Apex Site

Engineering Report
for
Pond 2 Final Closure

Prepared for:

Hecla Mining Company
6500 Mineral Drive, Suite 200
Coeur d'Alene, Idaho 83815-8788

Prepared by:

Monster Engineering Incorporated
3031 Bonner Spring Ranch Road
Laporte, Colorado 80535

August 17, 2003

Hecla Pond 2 Closure Plan comments 10/1/03

In Volume I, Section 2.2 Potential Borrow Source Materials Investigation, page 7, What is the proposed reclamation plan for these source material borrow sites? Will the areas be graded to allow for adequate revegetation? What native plant species and mulch will be used to control surface erosion? At what rates will grass/mulch be applied?

In Volume I, Section 3.0 Closure Alternatives, page 8, Have the proposed design alternatives incorporated earthquake standards to ensure long-term stability of Pond 2? If not, why was this not included?

In Volume I, Section 3.2.3 Alternative 2 (GCL) - Selected Alternative Cover System, page 12, How can Hecla better stabilize the embankment side slopes if bentonite becomes hydrated? Why isn't there any surface layer protection on the top cover areas (the outslopes will have a 2 inch thick layer of 1-inch rock)?

In Volume I, Section 4.2.4 Drainage and Consolidation, page 17, How will Hecla determine that overall settlement has slowed to an acceptable rate? What is the rate at which additional settlement will not compromise the long-term integrity of the overall cover system?

In Volume I, Section 4.2.6 Collection Ditch and Evaporation Pond Removal and Disposal, page 18, If lined evaporation ponds are re-constructed to contain additional leachate seepage, a protective netting/barrier should be used over the ponds to prevent migratory birds and/or other wildlife from being exposed to the leachate.

In Volume I, Section 4.4.3 Surface Layer Placement, page 20, A surface layer consisting of at least 2- inches thick of 1-inch rock should also be incorporated on the top surface for superior long-term erosion protection from wind and/or rainfall (see comment re: Section 4.4.4)..

In Volume I, Section 4.4.4 Diversion Channel Erosion Protection Placement, page 21, A 24 hour, 100-year storm event should be calculated to design runoff and erosion protection of the diversion channel (and final cover system). If greater peak flow results from using the 24 hour, 100-year storm event vs. the proposed 6-hour, 25 year design, then this figure should be used to ensure greater stability and erosion control.

In Volume I, Appendix C - HELP Modeling Results, Table 1 and Table 2 , The surface cover system in Table 1 identifies a 6-inch layer of rock on outslopes only for all alternatives, and Table 2 identifies an 8-inch surface layer. However the text in Section 4.4.3, page 20 and Table 3 - Final Closure Plan Alternatives, page 27 identifies the use of 2-inches of 1-inch rock. Why didn't the HELP Model calculations use the proposed rock thickness of 2-inches? A higher rate of runoff (inches/year) would occur with a 2-inch layer of rock on outslopes vs. a 6 or 8-inch layer of rock.

In Volume I, Appendix F - Runoff Evaluation and Erosion Protection Sizing Analysis (Figures, Data and Calculations), Runoff calculations should use "poor conditions" due to the recent fire that eliminated the vegetative cover within the area contributing storm water runoff to the diversion channel. A more conservative figure (i.e., 86) should be used for the Soil

Conservation Service curve number. It could be many years until groundcover is re-established as brush, neither sparse or dense.

In Volume I, Appendix H - Long-Term Monitoring and Maintenance Plan, The Engineering Report does not stipulate that Hecla "will" inspect annually to verify that the final cover system is functioning properly and to ensure that no significant problems are developing. Instead, the Report uses the words "should be inspected...". What is the length of time that Hecla proposes to be responsible for annually monitoring the condition of Pond 2 for cover system repairs, continued seepage migration, etc. after construction is completed? The preventative maintenance activities states that "maintenance may be required for two or three years...", but there is no other long-term commitment mentioned in the Report. Who will complete the annual maintenance inspection?

In Volume II, Section 1.5.6 Work Progress Schedule, page 9, EPA should receive a copy of construction progress reports once per month, including such items such as the existing time status, estimated time of completion, and cause of delays, if any.

In Volume II, Section 2.3.6 Field Quality Assurance, page 19, Upon completion of the surface cover system, the CQA Engineer should certify that the cover was completed according to all specifications in the Final Closure Plan. The written certification should be submitted to EPA Region 8 within 30-days of completing construction.

Other general concerns which should be incorporated into the Pond 2 Final Closure Plan: (1) an alternative for complete waste removal, including estimated construction costs and identification of off-site disposal location(s); and (2) all potential borrow material locations identified on a site map(s) (these borrow areas should not be within any sensitive tribal locations, e.g., areas containing tribal artifacts, or cultural significance).

Hecla
MINING COMPANY

VIA Federal Express Overnight Delivery

September 17, 2003

Amy Swanson, Esq.
EPA Region 8, 8ENF-L
999 18th Street, Suite 500
Denver, CO 80202-2466

Re: Hecla Mining Company Docket No. RCRA 8-99-06
Draft RCRA 7003 Consent Order
Ref: 8ENF-L

Dear Ms. Swanson:

This letter is in response to yours dated August 28, 2003 regarding the above referenced matter.

Enclosed are Hecla's comments to the draft Consent Order and two three ring binders that are the Closure Plan for the impoundment. Most of the changes to the existing Consent Order were necessary to incorporate the concept that we start off with an approved Closure Plan as Exhibit A to the Consent Order. That concept has been previously discussed with EPA and is essential to Hecla.

It should be apparent from the enclosed Closure Plan that we have been diligent in addressing closure of the impoundment rather than neglecting the matter as implied in your letter. To date, our investigation has revealed there is no imminent danger to human health or the environment from the impoundment. Nonetheless, Hecla is committed to closing the impoundment provided the work required of us is reasonable.

Please contact me if you would like to further discuss this matter. Any questions concerning the Closure Plan should be directed to Chris Gypton at (208) 769-4135 or to his address noted in the Consent Order.

Very truly yours,

John N. Galbavy

John N. Galbavy, Esq.
C: John R. Jacus, Esq.
Chris Gypton, Hecla

LEAK DETECTION
PIEZOMETER INSTALLATION
AND SOIL SAMPLING

May 10, 2001

Prepared for:

OMG Americas Apex Operations
P. O. Box 2407
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St. George, Utah 84777

Prepared by:

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8160 South Highland Drive
Sandy, Utah 84093

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REFERENCES

Applied Geotechnical Engineering Consultants, 1997. *Geotechnical Investigation, OMG/Apex Expansion, Washington County, Utah,* November 21.

Applied Geotechnical Engineering Consultants, 2000. *Geotechnical Investigation, OMG/Apex Expansion, Washington County, Utah,* July 7.

Steffen Robertson and Kirsten (U.S.), Inc., 1990. *Construction Evaluation of Pond 3A and Pond 1-A/1-B, Apex Project, St. George, Utah,* March.

Steffen Robertson and Kirsten, 1984. *Groundwater Supply Availability for the Apex Project, Washington County, Utah,* May.

Utah Geological Survey, Division of Utah Department of Natural Resources, 1994. *Geologic Map of the Shivwits Quadrangle, Washington County,* Utah.

1.0 INTRODUCTION

1.1 Background

In accordance with the proposal submitted by JBR Environmental Consultants, Inc. (JBR) on December 28, 2000, this report is submitted to OMG as reference information. The report includes a description of the work performed, results of the data evaluation, geologic description, bedrock profile, conclusions, and recommendations.

The scope-of-work was completed between January and April 2001. The field work was coordinated with OMG Americas Apex Operations (OMG) personnel and conducted February 5 through 14, 2001.

Figure 1 shows the location of the site in relation to nearby cities, access roads and plant facilities.

1.2 Objectives

The objective of this study was to determine the presence of and potential for seepage to occur from the four (4) lined holding ponds located on the site. This would be accomplished by installation of fifteen (15) leak detection piezometers, hereafter referred to as monitoring wells, installed at select locations around the ponds.

Specifically, the following tasks were performed:

- Obtain and review existing geologic, geotechnical and water well drilling information provided by OMG and as available from public information sources.
- Samples taken at five (5) foot intervals, strata change and/or soil to bedrock interface for field classifications and laboratory testing, as authorized by OMG.
- Establish the slope of the upper bedrock surface across the site from review of the geologic literature, site observations and sampling during installation of monitoring wells.
- Provide a monitoring well observation procedure and schedule for use in determining the presence of any seepage pond solutions or meteoric waters.

2.0 SCOPE AND DESCRIPTION OF WORK

2.1 Data Review

A review of the available geologic, geotechnical, and water well installation reports provided by OMG was conducted to determine the characteristics of the alluvial soils and bedrock underlying the site. Review was also made of a geologic map and report compiled by the Utah Geologic Survey in 1994. These reports and map are listed in the reference section of the report.

2.2 Piezometer (Monitoring Well) Installation

Fifteen (15) monitoring wells were installed to determine the thickness of the soil cover, presence of excessive moisture, and depth to bedrock across the site as exists near the four (4) solution holding ponds. The wells were installed at both up- and down-gradient locations of each pond as shown on Figure 2.

The wells were installed using a Hollow-Stem Auger drilling rig operated by Mountain States Drilling Company of Beaver Dam, Arizona. No water or chemical additives were used during the drilling or well construction, except for the treated water from the Reverse Osmosis system produced by OMG from their processing operations, to mix the grout and concrete during well construction. For reference, the logs for the wells are included in Appendix A, showing the lithology encountered and the well construction details including the screen depths and annulus grouting zones. Each well was completed with a locking, steel stand-pipe cemented into the ground surface, as shown in Figure 3. Construction details of each well are included in Table A-1, in Appendix A.

2.3 Soil Sampling/Bedrock Determination

Samples of the soils and upper bedrock surface were taken for sediment classification and for laboratory testing, as authorized. The samples were taken using a Standard 1-1/2 inch diameter Split-Spoon Sampler, driven 18-inches through the inside and at the bottom of the auger to obtain an undisturbed sample. The sampler is driven by dropping a 140 pound weight 27-inches and counting the blows for each 6-inch interval or to sampler refusal. This information is used to provide the relative density of the sediments and is recorded on the well logs at each sampling interval. Where drive samples were unable to be taken, grab samples were collected for classification purposes.

During drilling, a record was also made of any groundwater or seepage water present in the wells as to depth and location. This information is also included on the drilling logs included in Appendix A. No groundwater or seepage water was observed in any of the monitoring wells installed.

3.0 DISCUSSION

3.1 Soil Characteristics

Based on the literature review, it was determined that the alluvial colluvial soils exist in variable thicknesses from 9 - 34 feet depending upon location. These sediments range between fine grained sandy silts, fine-to-coarse sand and fine-to-coarse gravels with cobbles and boulders.

Some calcification also exists in the sediments with gypsum partings evident, but apparently not in continuous seams.

Results of the grain size analysis performed by OMG indicated that the soils ranged between a SM/GM (silty fine sand and gravel) mixture to a SW/SP (fine to coarse gravelly sand) classification with over 90 percent being retained on the 100 mesh sieve. Meaning, that most of the sediments tested have less than 10 percent or less silt and clay. These sediments were found to be overlain by a thin (0-5 foot) layer of unconsolidated fill materials usually containing cobbles and boulders, depending upon the location. Appendix B contains the graphic boring logs generated by the field geologist during drilling of the monitoring wells.

Moisture contents of the soils tested were generally very low, averaging 7.7 percent, typical of the arid, dry conditions inherent to the area. Table 3-1 shows the results of moisture tests conducted by OMG on samples taken from the expected flow zones during monitoring well installation at the soil-to-bedrock interface on wells located down gradient of the holding ponds. Only one sample, MW 3-3, showed a moisture content higher than the normal range encountered during well installations. Monitoring wells MW 3-2, MW 2-2 and MW 1-4 also showed slightly higher levels of moisture. The elevated level of moisture in these wells is believed to be from infiltration of meteoric waters along the interface at the topographically low point in the valley.

Table 3-1: Moisture Contents of Soil Samples of Soil Samples at Bedrock Contacts From Monitoring Well Installations

Monitoring Well No.	Sample Depth (Ft)	Soil Type *	Moisture Content (%)
MW 1 - 1	20.0	Fine sand & gravel w/some silt (SW)	6.7
MW 1 - 2	15.0 - 20.0	Fine sand & gravel w/some silt (SW)	9.6
MW 1 - 3	20.0	Fine sand & gravel w/some silt (SW)	8.6
MW 1 - 4	30.0	Fine sand & gravel w/some silt (SW)	12.3
MW 2 - 1	10.0 - 10.5	Silty sand w/ some fine gravel (SM)	7.7
MW 2 - 2	20.0	Fine sand & gravel w/some silt(SW)	10.7
MW 2 - 3	10.0 - 13.0	Fine sand & gravel w/some silt (SW)	5.6

Monitoring Well No.	Sample Depth (Ft)	Soil Type *	Moisture Content (%)
MW 3 - 1	24.5 - 25.5	Fine sand & gravel w/some silt (SW)	7.1
MW 3 - 2	20.0	Silty fine sand w/gravel, dense (SM)	11.7
MW 3 - 3	20.6	Silty fine sand w/gravel/cobble (SM)	16.1
MW 3 - 4	15.0	Silty fine sand w/ fine gravel (SM)	3.4
MW 3 - 5	15.0	Fine to coarse sand & gravel w/cobbles (GM)	0.7
MW 4 - 1	25.0	Fine to med. sand w/some silt (SW)	1.6
MW 4 - 2	35.0	Fine to coarse sand w/some silt (SW)	7.2
MW 4 - 3	10.0	Fine to med. Sand w/some silt (SW)	7.0
		Average	**7.7**

* Based on the Unified Soil Classification System

3.2 Bedrock Conditions

From a review of the existing geologic literature (UGS, 1994), and from reports of the geotechnical investigations (SRK, 1990), (AGEC, 1997) and (AGEC, 2000) conducted for holding pond and processing facility construction, the bedrock underlying the site consists of the shaley, gypsiferous mud/siltstone Shnabkaib member of the middle Moenkopi Formation of Triassic Age. These sediments are light-gray in color, dense to very dense and intercalated with gypsum. This member is reported to range around 800 feet in thickness in the general vicinity, (USG, 1994).

Above and below the middle Shnabkaib member are the Upper and Middle Red members of the Moenkopi. The Upper Red member consists of reddish-brown thin-bedded siltstones and sandstones with minor gypsum deposits. The Middle underlying Red member consists of a pale reddish-brown, thin-bedded siltstone and mudstone interbedded with thin layers of gypsum with a reported thickness of 300-350 feet. Two other members of the Moenkopi exist below these members with a reported thickness of 370 - 410 feet which overlies the Harrisburg Member of the Kaibab Formation of Permian Age, an inter-bedded, fossiliferous limestone with chert nodules and gypsum beds.

In the immediate vicinity of and around the site, these sediments are reported (UGS, 1994) to exist in a relatively consistent manner, as shown in the Bedrock Surface Profiles, Figure 4 and the Geologic Map and Cross Section, Figure 5. The only exception being where they have been intercepted by structural features, such as faulting and folding which has resulted in some displacement and warping of the sediments to form broad anticlinal and synclinal features in the surrounding area. Since most of these features are buried under unconsolidated alluvial or colluvial sediments and overlying younger bedrock sediments, effects are minimal for the purposes of this study. Table 3-2 shows the depth to and the elevations of the upper bedrock surface encountered in each monitoring well.

Table 3-2: Depths to Bedrock and Bedrock Elevations at Monitoring Well Locations

Monitoring Well No.	Collar Elevation (Ft. AMSL)	Depth to Bedrock (Ft.)	Bedrock Elevation (Ft. AMSL)
MW 1 - 1	3680	19	3661
MW 1 - 2	3678	24	3654
MW 1 - 3	3671	23	3648
MW 1 - 4	3672	33	3639
MW 2 - 1	3683	13	3670
MW 2 - 2	3675	20	3655
MW 2 - 3	3684	15	3669
MW 3 - 1	3639	25	3614
MW 3 - 2	3639	23	3616
MW 3 - 3	3634	22	3612
MW 3 - 4	3633	18	3615
MW 3 - 5	3646	21	3625
MW 4 - 1	3653	26	3627
MW 4 - 2	3653	38	3615
MW 4 - 3	3648	9	3639
		Average Depth: 22	

A review of the study performed by SRK, (1984) for the purpose of determining groundwater supply availability, confirms the existence and characteristics of the bedrock formations underlying the site to the depths drilled for water well installation purposes. Well ASW-2 was drilled to a depth of 455 feet, the deepest of the three wells drilled. Groundwater was encountered at a depth of 299 feet in ASW-2, at 256 feet in ASW-3 and 195 feet in ASW-4. Well ASW-1 was abandoned at a total depth of 87 feet due to caving and high circulation loss apparently within a limestone member of the Middle Moenkopi Formation. Figure 2 shows the location of these water wells with respect to the holding ponds and monitoring wells installed by JBR.

3.3 Geologic Structure

In general, the site lies near the boundary of the Basin and Range and the Colorado Plateau physiographic provinces. Geologic structures in this area were formed mostly during the Late Cretaceous and Paleocene times approximately 60 million years ago. About 20 million years ago, faulting and warping began which resulted in the features existing today in the area.

Based on a review of the geologic literature (UGS, 1994), two faults exist in the immediate area of the site. These features are reverse strike-slip and oblique-slip lateral faults that parallel one another forming a graben (down-dropped section) and are located on the east and west sides of the site about 0.5 miles apart, as shown on Figure 5.

The westward structure, labeled as the Reef Reservoir Fault, dips steeply to the west at about 15 degrees and extends from a point about 9 miles to the south of the site northward to a location about 1 mile to the north of the site where it is believed to merge with the Gunlock Fault. The Reef Reservoir Fault has an estimated vertical stratigraphic displacement of about 1400 feet. No exposures of the fault exists in the immediate vicinity. The Wittwer Fault, existing to the east of the site, has a vertical displacement of a few hundred feet, but a lateral displacement of about 0.5 miles. This fault also dips steeply, but in an easterly direction of about 10 degrees. Both of these features are in juxtaposition on the east limb of the north-plunging Shebit Anticline of Late Cretaceous time.

The Shebit Anticline exists on the east side of the Reef Reservoir Fault and is mostly buried at the site location, as shown on Figure 5. The Wittwer Canyon Anticline is located to the west of the Reef Reservoir Fault, also as shown on Figure 5. The Shebit Anticline has been displaced at least 0.5 miles southward by action of the faults. Evidence of this movement is not visible due to the soft, poorly consolidated and fine grained nature of the Moenkopi Formation.

4.0 CONCLUSIONS

Based on the studies associated with the Objectives and Scope of Work of this project, the following conclusions have been reached and are presented for your information:

- Soil sediments in the area were found to be consistent across the site based on soil sampling efforts during monitoring well installation. A well-sorted, dense, fine-to-coarse grained sand and gravel with some silt was found to exist on top of the bedrock at most monitoring well locations which could act as a water flow zone.

- Bedrock conditions at the site was also found to be fairly uniform in that the middle Shnabkaib member of the Moenkopi Formation was encountered as a dense, very fine grained siltstone at all monitoring well locations, except well MW 2-3 located below Pond 2. At this location, a fine grained, dense sandstone was found which is also a part of this middle member. Figure 4, Bedrock Surface Profile, illustrates the relationship of the upper bedrock surface to overlying soils, pond facilities and monitoring well locations.

- Moisture contents of soil samples taken at the potential flow zone, the soil-to-bedrock interface, did not indicate sufficient amounts to signify that seepage was occurring from any of the ponds. The average moisture content of samples taken from each well was shown to be in the range typical to the arid zone of the site. The slightly elevated moisture contents for samples from wells, MW 2-2, MW 2-3, MW 3-3 and MW 4-1 are believed to be from meteoric water infiltration rather than from pond seepage at this time. Chemical analysis is planned by OMG on certain soil samples taken at the soil-to-bedrock interface in the future.

- Groundwater is believed to exist at depths between 195 feet and 299 feet, as reported during water supply drilling and well installation activities in the past. Other than some minor moisture accumulation on top of the bedrock, no indication of a shallow, distinct groundwater flow zone was noticed during drilling and installation of the monitoring wells at the site.

5.0 RECOMMENDATIONS

The following recommendations are presented for your consideration and are based on the results of the studies conducted to fulfill the Objectives of this study.

5.1 Piezometer Well Monitoring Technique and Schedule

The recommended technique for monitoring the (piezometer leak detection) wells installed by JBR as part of this project, is to use a water level sounding device, as discussed during our site investigation, which will indicate, by flashing light and beeper, if any water or solution is present in the well bore and the depth at which the water exists. By subtracting the height of the PVC well casing sticking-up above the ground surface, as contained in the protective steel casing, the actual water level depth and elevation can be calculated.

Due to the lack of groundwater or pond solution found during installation of the monitoring wells, it is recommended that effective monitoring of the wells could be accomplished on a quarterly basis. This would allow OMG to determine if any pond seepage is occurring or if shallow meteoric waters are migrating through the area. Should waters be found in any of the wells, the monitoring schedule should be increased to monthly to assist in determining the source and chemical parameters.

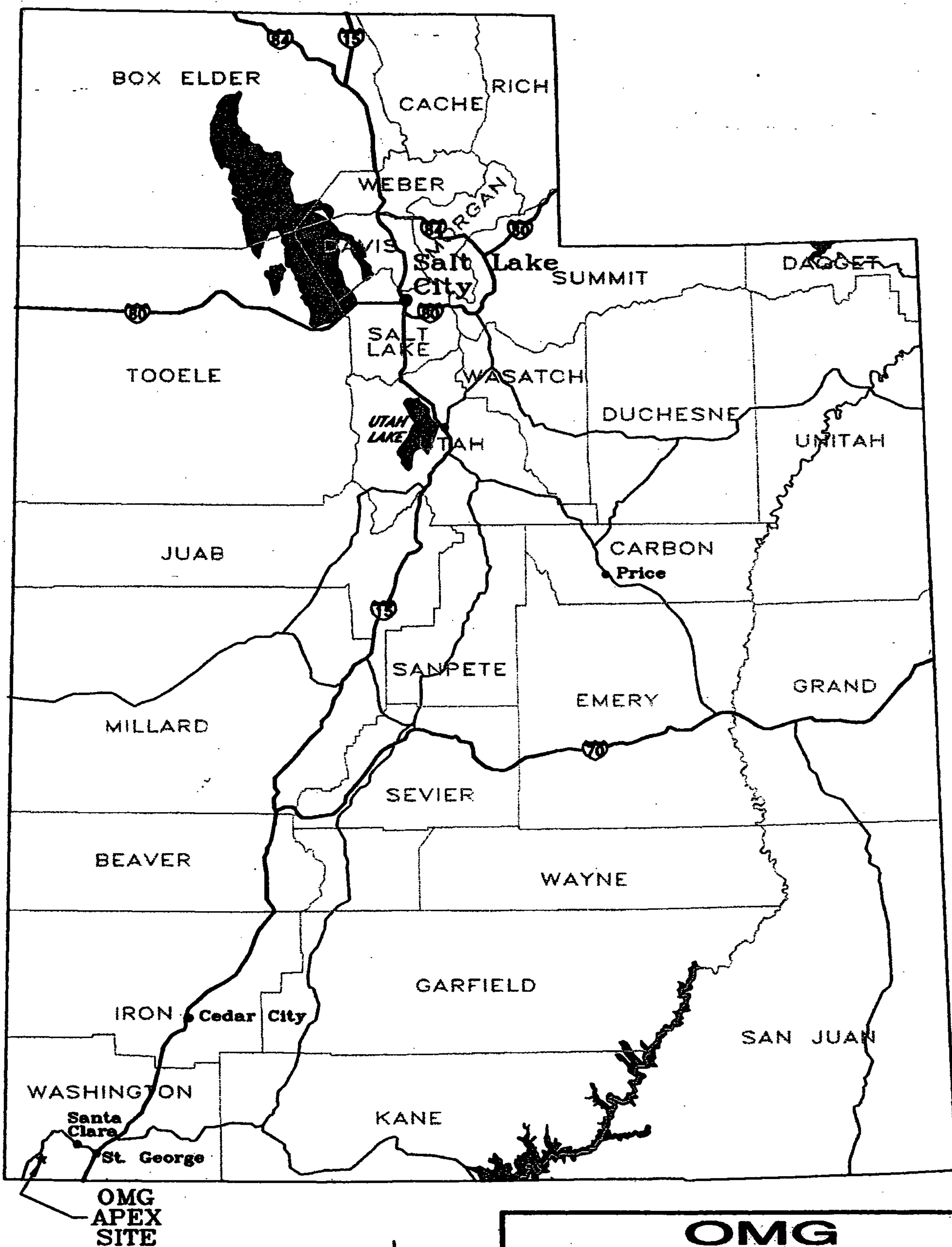
It is also suggested that a record keeping system be developed to keep track of all data obtained during the monitoring program. The system should list the monitoring well number, date and time of sounding, results of sounding, i.e, depth to water or dry well, and any comments as to condition of the well or climatic events that could cause water flow in the well.

5.2 Laboratory Testing

Should water and/or pond solution be found in any monitoring well, the well should be sampled and laboratory testing conducted to determine if the waters are meteoric or from pond seepage.

5.3 Additional Studies

JBR does not recommend any additional studies at this time. However, should waters be found in any of the wells, especially those located below the ponds, then, consideration should be given to performing specific studies and/or installing additional monitoring wells directed towards determining the source of the waters.



N

NOT TO SCALE

OMG

APEX OPERATION

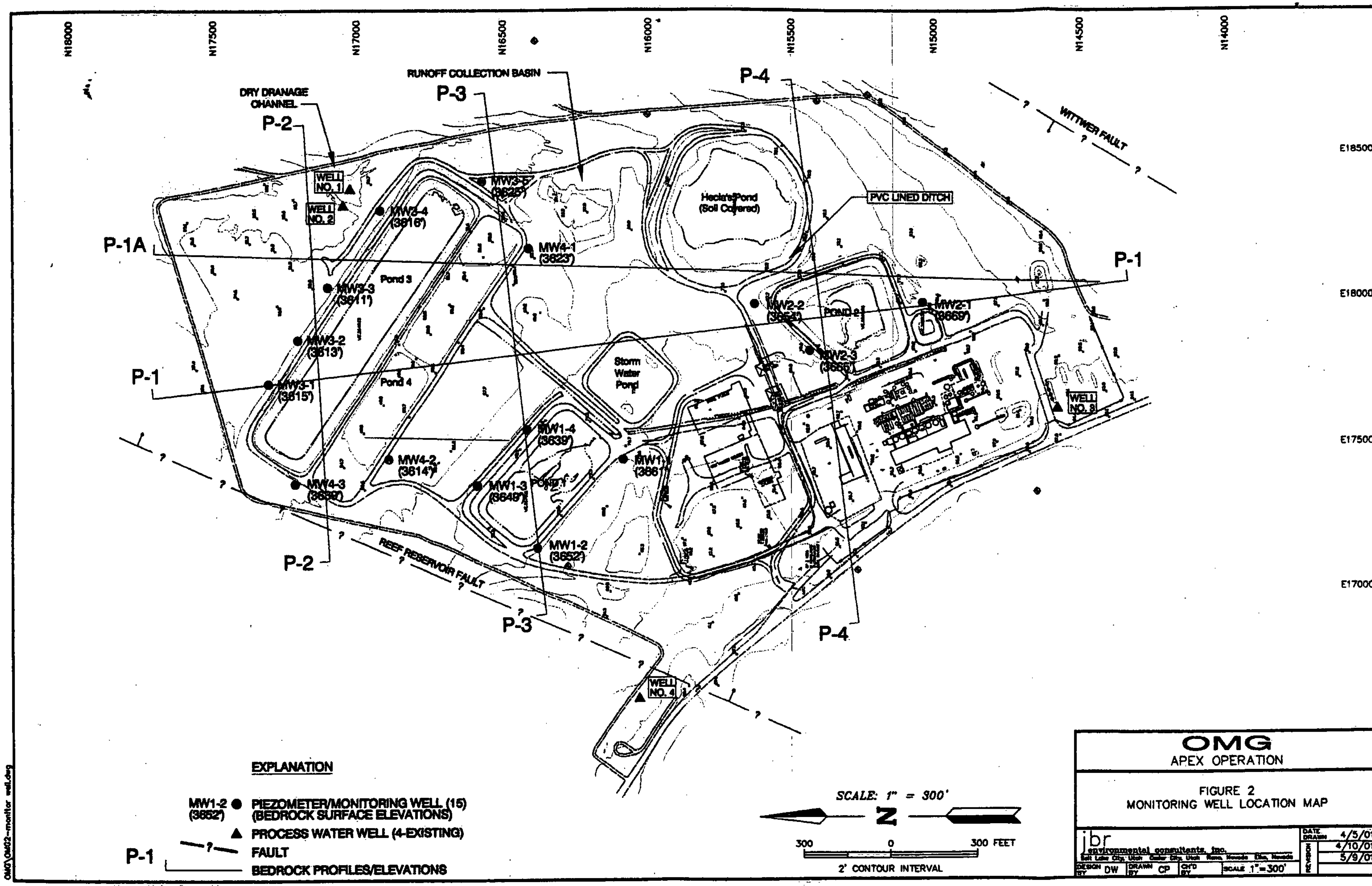
FIGURE 1
SITE LOCATION MAP

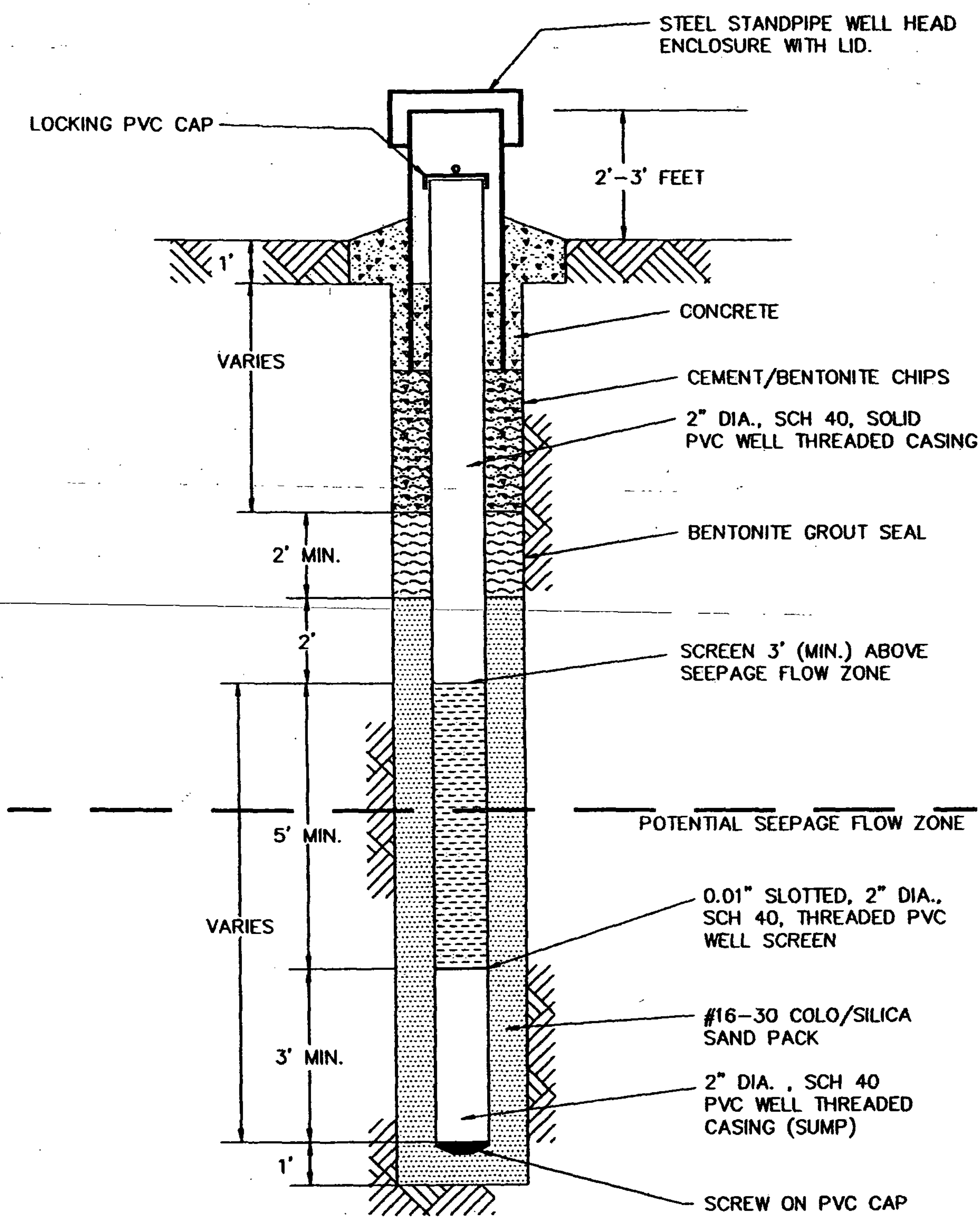
jbr environmental consultants, inc.
Salt Lake City, Utah Cedar City, Utah Reno, Nevada Elko, Nevada

DESIGN BY	DW	DRAWN BY	CP	CH'D BY		SCALE	NTS

DATE DRAWN	3/22/01
REVISION	4/10/01

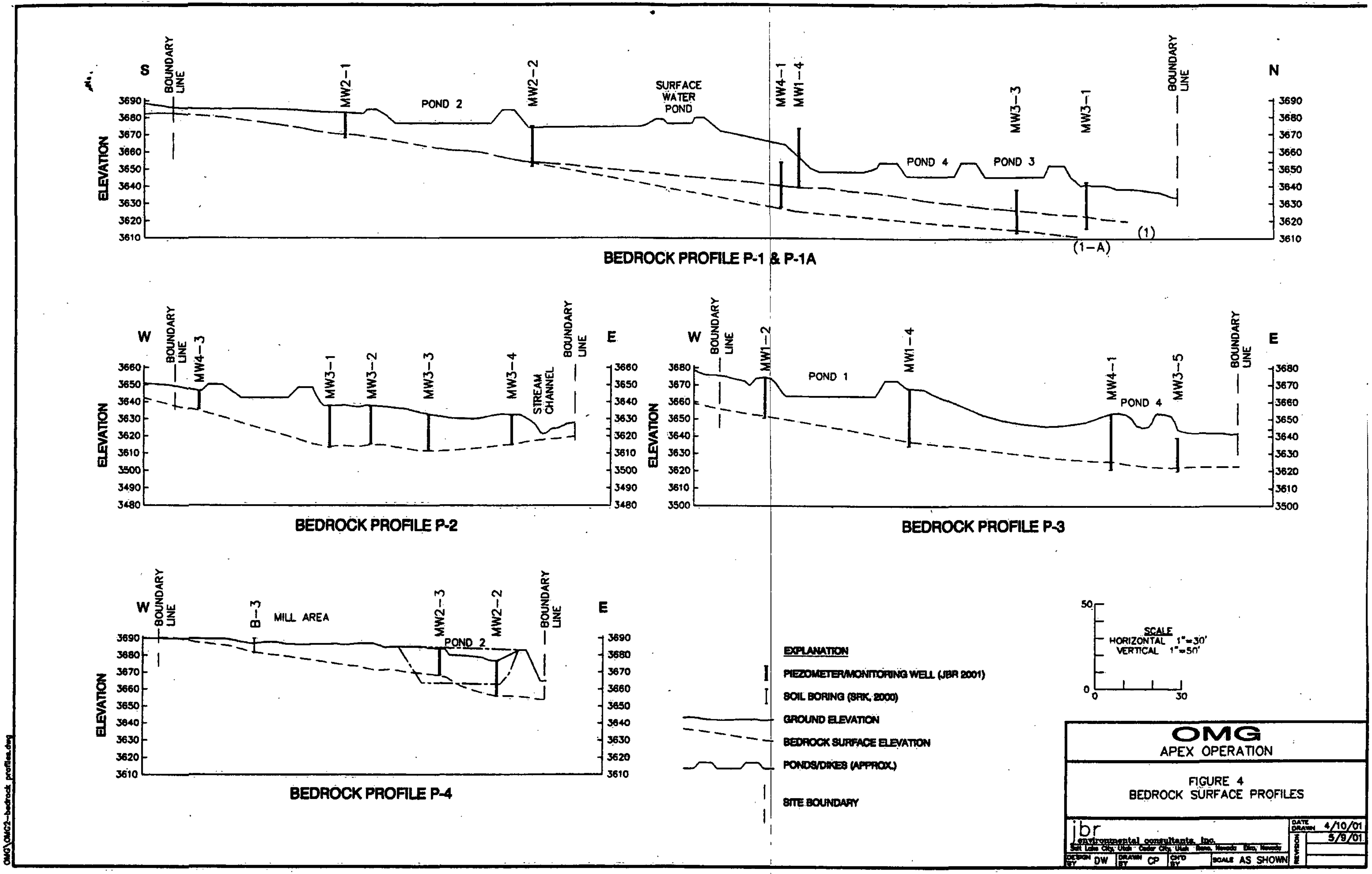
OMG\OMG2-LOCATION.DWG


N18000
N17500
N17000
N16500
N16000
N15500
N15000
N14500
N14000
E18500
E18000
E17500
E17000
RUNOFF COLLECTION BASIN
DRY DRANAGE CHANNEL
P-1A
P-1
P-2
P-3
P-4
WITTWER FAULT
WELL NO. 1
WELL NO. 2
WELL NO. 3
WELL NO. 4
Hecla's Pond (Soil Covered)
PVC LINED DITCH
MW3-5 (3625')
MW3-4 (3616')
MW4-1 (3623')
MW3-3 (3611')
MW3-2 (3613')
MW3-1 (3615')
MW4-2 (3614')
MW4-3 (3639')
MW1-4 (3639')
MW1-3 (3649')
MW1-2 (3652')
MW2-2
MW2-1 (3669')
MW2-3
Pond 3
Pond 4
Pond 2
Pond 1
Storm Water Pond
REEF RESERVOIR FAULT
EXPLANATION
MW1-2 (3652') PIEZOMETER/MONITORING WELL (15) (BEDROCK SURFACE ELEVATIONS)
PROCESS WATER WELL (4-EXISTING)
FAULT
BEDROCK PROFILES/ELEVATIONS
SCALE: 1" = 300'
N
300 0 300 FEET
2' CONTOUR INTERVAL
OMG
APEX OPERATION
FIGURE 2
MONITORING WELL LOCATION MAP
jbr environmental consultants, inc.
DATE DRAWN 4/5/01
4/10/01
5/9/01
DESIGN BY DW
DRAWN BY CP
SCALE 1"=300'

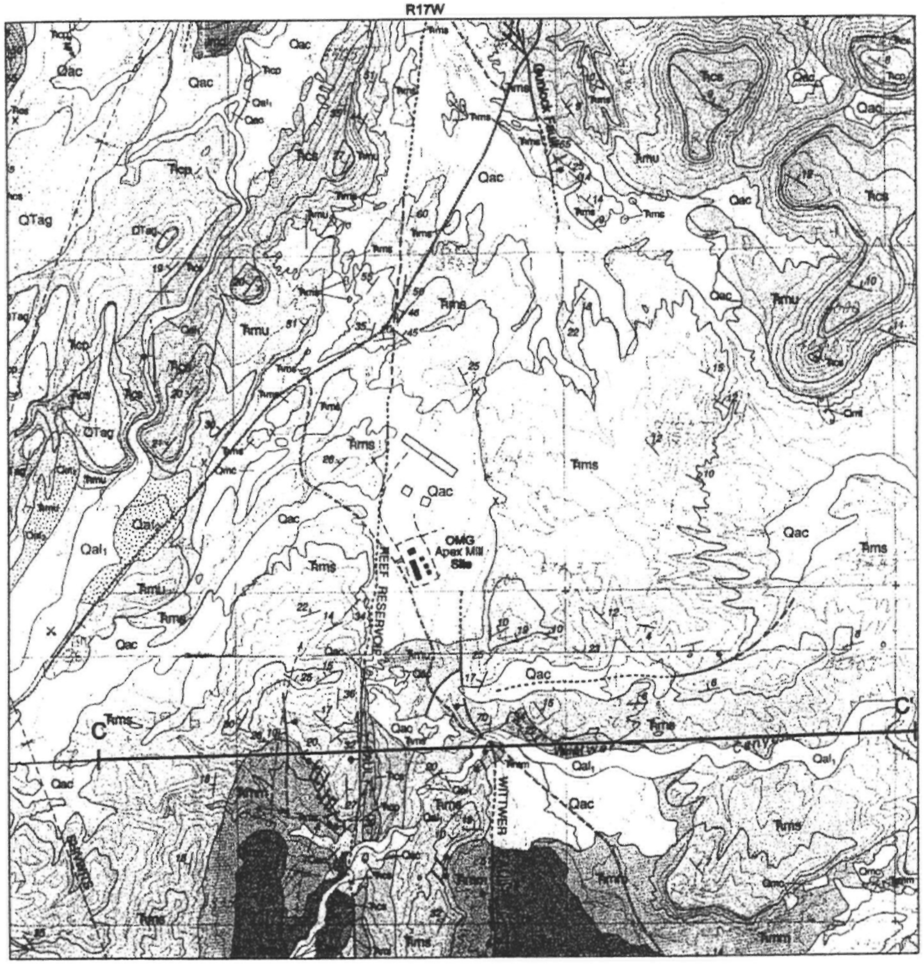


OMG APEX OPERATION		
FIGURE 3 TYPICAL PIEZOMETER WELL COMPLETION		
jbr environmental consultants, inc. Salt Lake City, Utah Cedar City, Utah Reno, Nevada Elko, Nevada	DATE DRAWN	12/21/00
	REVISION	4/12/01
DESIGN BY DW — DRAWN BY CP — CH'D BY — SCALE NTS		

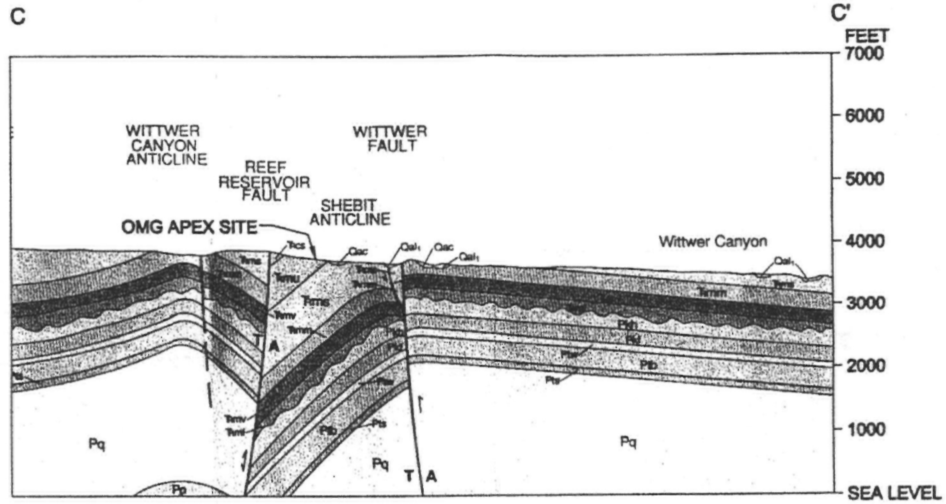
OMG\omg2-well.dwg



BEDROCK PROFILE P-1 & P-1A
S
N
BOUNDARY LINE
MW2-1
POND 2
MW2-2
SURFACE WATER POND
MW4-1
MW1-4
POND 4
POND 3
MW3-3
MW3-1
(1)
(1-A)
ELEVATION
BEDROCK PROFILE P-2
W
E
MW4-3
MW3-1
MW3-2
MW3-3
MW3-4
STREAM CHANNEL
BEDROCK PROFILE P-3
MW1-2
POND 1
MW1-4
MW4-1
POND 4
MW3-5
BEDROCK PROFILE P-4
B-3
MILL AREA
MW2-3
MW2-2
POND 2
EXPLANATION
PIEZOMETER/MONITORING WELL (JBR 2001)
SOIL BORING (SRK, 2000)
GROUND ELEVATION
BEDROCK SURFACE ELEVATION
PONDS/DIKES (APPROX.)
SITE BOUNDARY
SCALE
HORIZONTAL 1"=30'
VERTICAL 1"=50'
OMG
APEX OPERATION
FIGURE 4
BEDROCK SURFACE PROFILES
jbr environmental consultants, inc.
DATE DRAWN 4/10/01
5/9/01
DESIGN BY DW
DRAWN BY CP
SCALE AS SHOWN
OMG\OMG2-bedrock profiles.dwg



GEOLOGIC MAP



CROSS SECTION C-C'

N

2000 0 2000 FEET

REFERENCE: UTAH GEOLOGICAL SURVEY MAP 153, 1994

OMG APEX OPERATIONS	
FIGURE 5 GEOLOGIC MAP AND CROSS SECTION C–C'	
jbr environmental consultants, inc. Salt Lake City, Utah Cedar City, Utah Reno, Nevada Elko, Nevada	DATE DRAWN 4/5/01; REVISION 4/10/01
DESIGN BY DW; DRAWN BY CP; CH'D BY; SCALE 1"=2000'	

OMG\OMG2-GEO.DWG

jbr environmental consultants, inc.

BORING/MONITOR WELL NO.: MW 1-1 **COMPLETION DATE:** 02/06/01
LOCATION: SOUTHWEST CORNER POND #1
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA (FLIGHT/PILOT) **BORING DIAMETER:** 5/6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	SOIL CLASS	SAMPLES TYPE	REC. %	I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0–10	GM	G		NA	NA		Light brown sand with fine to coarse gravel unconsolidated, grading with some cobbles, fine to coarse gravel (fill).
10–15	SW	G		NA	NA		Reddish brown fine to coarse sand with some fine gravel, dense, (alluvium/colluvium).
15–23	SW	D	85	1.5" SS	6"-37/140# 6"-42		Reddish brown fine sand with fine gravel some silt, and thin gypsum seams.
23–25	ML	D	100	2" SS	2"-100		Tan grey siltstone, very dense, (Moenkopi Fm., bedrock)
25							TD 25.0'

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT

GRAVEL PACK: 16–30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 1-2 — COMPLETION DATE: 02/07/01

LOCATION: NORTHWEST CORNER POND # 2 - ABOVE POND

PROJECT NAME: OMG APEX — PROJECT NO.: OMG-01

BORING TYPE: HSA — BORING DIAMETER: 5/6.5 INCH — LOGGED BY: DLW

DEPTH FEET	SOIL CLASS	SAMPLES TYPE	REC. %	I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0							Tan sandy soil with fine coarse gravel/cobbles, unconsolidated, medium dense (fill).
5	GM	G					
							Brown fine to medium sand with gravel/cobbles
10		G					
15							(Alluvium/colluvium)
		G					Reddish brown fine sand with fine gravel some silt, dense, gypsum seams, grading more dense, moist.
20	SW	D		1.5" SS	6"-19 6"-28		
25		D		1.5" SS	6"-50		
30	ML	D		1.5" SS	6"-25 2"-53		Tan/gray siltstone, very dense (Moenkopi Fm., bedrock)
							TD 30.0'

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED

CASING: 5" SQUARE SURFACE STICK-UP 2.5'

SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT

GRAVEL PACK: 16-30 COLORADO SILICA SAND

ANNULAR SEAL (1): BENTONITE CHIPS

ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 1-3 **COMPLETION DATE:** 02/07/01
LOCATION: NORTHWEST CORNER POND # 1 - BELOW POND
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 5/6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	WELL CONST.	GRAPHIC LOG	SOIL CLASS	SAMPLES TYPE	SAMPLES REC. %	SAMPLES I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0									Sandy gravel soil with cobbles (fill).
5			SM	D		1.5" SS	6"-20/140# 5"-50		Light brown/tan silty fine sand with 10% fine gravel, moderately dense.
10			GM	G					Grading with coarse gravel, cobbles, less silt, fine sand, light brown, dense, unconsolidated. (Colluvium/alluvium)
15			SP	D		2" SS	6"-40 6"-40		Reddish brown fine sand, dense, uniform, damp.
20			SW	D		2" SS	6"-20 6"-31		Reddish brown sand with fine gravel some silt, calcified, gypsum nodules, dense, damp.
25				D			6"-35 6"-40		
			ML	D			6"-35 Δ -50		Tan gray siltstone. (Moenkopi Fm., bedrock).
30									TD 29.0'
35									
40									
45									
50									
55									
60									
65									
70									

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT

▨ GRAVEL PACK: 16–30 COLORADO SILICA SAND
▤ ANNULAR SEAL (1): BENTONITE CHIPS
▩ ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 1-4 **COMPLETION DATE:** 02/08/01
LOCATION: NORTHWEST CORNER POND # 1 - BELOW DIKE
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 5/8.5 INCH **LOGGED BY:** DLW

DEPTH FEET	SOIL CLASS	SAMPLES TYPE	REC. %	I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0							Sandy gravel/cobbles (fill).
5		☒					Light brown silty fine sand with fine to medium gravel, very little fines, unconsolidated, (alluvium/colluvium), damp.
10	GM	G	100				
							Grading with some cobbles, dense.
15		D		1.5" SS	2"-55/140#		
20		G					
25		D					
							Grading, more dense.
30		D	100	1.5" SS	6"-12/140# 6"-20		
	SW						Reddish brown fine sand with fine to medium gravel, some silt, moderately dense, damp.
	ML						Light gray/tan siltstone, (Moenkopi FM., bedrock).
35		D	80		6"-33 6"-36		
							TD 36.0'

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT
GRAVEL PACK: 16-30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 2-1 **COMPLETION DATE:** 02/05/01
LOCATION: SOUTH POND #2
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	SOIL CLASS	SAMPLES TYPE	REC. %	I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0	SM						Reddish brown silty sand with fine gravel and gypsum particles.
5		D	75		6"-25 6"-27		Alluvium
10	SM	D	80		6"-100		Tan silty sand with some gypsum, very dense, dry, some fine gravel.
15	ML	D	20		2"-100		Gray siltstone (Moenkopi Fm., bedrock).
							TD 14.2' @ Refusal

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: N/A – 5" SQ. SS PROT. STICK-UP 2.5
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT/CAPS
GRAVEL PACK: 16-30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): CEMENT GROUT

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BORING/MONITOR WELL NO.: MW 2-2 **COMPLETION DATE:** 02/05-06/01
LOCATION: NORTHEAST CORNER POND #2
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA (FLIGHT/PILOT) **BORING DIAMETER:** 5/6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	WELL CONST.	GRAPHIC LOG	SOIL CLASS	SAMPLES TYPE	SAMPLES REC. %	SAMPLES I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0			FILL	G					Reddish brown silty sand with fine gravel (fill).
5			GM	G					Light brown, silty fine sand with fine gravel/calcified, dense to very dense.
10			SW	G					Reddish brown fine sand and gravel with some silt.
15									
20				D		2" SS	11-6"/140# 27-6"		(Alluvium)
			ML						Tan/gray siltstone with thin calcified seams, dense. (Moenkopi Fm., bedrock).
25				D		2" SS			
									TD 25.6'
30									
35									
40									
45									
50									
55									
60									
65									
70									

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT

GRAVEL PACK: 16–30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 2-3 **COMPLETION DATE:** 02/05/01
LOCATION: NORTHWEST CORNER POND - BELOW DIKE
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	SOIL CLASS	SAMPLES TYPE	REC. %	I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0	BOULDER FILL						Red sandstone boulders.
6		G					
10	SM	G					Reddish brown silty fine sand, dense, damp with some fine gravel.
14	SS	D		2" SS	100-6"		Light brown fine grained sandstone (Moenkopi Fm., bedrock) with upper weathered surface 1.5'.
19.3		D	20	2" SS	50-2"		TD 19.3' @ Refusal

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: N/A – 5" SQ. SS PROT. STICK-UP 2.5
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT/CAPS
GRAVEL PACK: 16-30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): CEMENT GROUT

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BORING/MONITOR WELL NO.: MW 3-1 **COMPLETION DATE:** 02/10/01
LOCATION: NORTHWEST CORNER POND #3 - BELOW DIKE
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW

DEPTH FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70

SOIL CLASS	SAMPLES TYPE	SAMPLES REC. %	SAMPLES I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
SW						Reddish brown sandy gravel, fine to medium (fill).
GM	G G					Brown fine medium sand and gravel with cobbles, unconsolidated, moderately dense, (colluvium/alluvium).
GP	G					Fine to medium gravel, no fines, possible stream channel.
SM						Reddish brown fine sand and gravel with some silt, very dense.
ML	D		2" SS	6"-20/140# 5"-50		Tan/gray siltstone (Moenkopi Fm., bedrock).
						TD 30'

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT
GRAVEL PACK: 16–30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 3-2 **COMPLETION DATE:** 02/10-12/01
LOCATION: CENTER POND #3 - BELOW DIKE
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	WELL CONST.	GRAPHIC LOG	SOIL CLASS	SAMPLES: TYPE	SAMPLES: REC. %	SAMPLES: I.D./INT.	BLOW COUNT	SOIL ANALYSES (TYPE: UNITS:)	DESCRIPTION
0			SW						Reddish brown fine sand with fine gravel (fill).
5			GM	G					Light brown fine to coarse sand and gravel with cobbles, unconsolidated, medium dense. (Colluvium/alluvium)
10									
			GP	W					Fine to medium gravel, no fines, possible stream channel.
15			SM	D		2" SS	6"-20/140# 6"-11		Brownish red silty fine sand with gravel, dense, moist, grading, very dense, uniform dry.
20				D		2" SS	6"-20 6"-25		
			ML						Light tan/gray siltstone (Moenkopi Fm., bedrock).
25				D		2" SS	6"-50/140#		TD 25.6'
30									
35									
40									
45									
50									
55									
60									
65									
70									

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT
GRAVEL PACK: 16–30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 3-3 **COMPLETION DATE:** 02/12/01
LOCATION: NORTH CENTER POND #3 - BELOW DIKE
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	SOIL CLASS	SAMPLES TYPE	SAMPLES REC. %	SAMPLES I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0–3	SW						Brown sandy gravel with cobbles (fill).
3–13	GM	C					Light brown fine to coarse sand and gravel with cobbles, unconsolidated, moderately dense. (Colluvium/alluvium)
10		D		2" SS	6"-12/140# 6"-15		
13–22	SM						Reddish brown silty fine sand sith fine gravel, dense, damp.
15		D		2" SS	6"-8 6"-15		
18							Less dense, more silt, gravel.
20		D		2" SS	6"-3 6"-4		Moist at bedrock contact, no evidence salt.
22–28	ML						Tan/gray siltstone (Moenkopi Fm., bedrock).
25		D		2" SS	3"-50		
28							TD 28'

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT
GRAVEL PACK: 16-30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 3-4 **COMPLETION DATE:** 02/12-13/01
LOCATION: NORTHEAST CORNER POND #3 - BELOW DIKE
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	SOIL CLASS	SAMPLES TYPE	REC. %	I.D./INT.	BLOW COUNT	SOIL ANALYSES (TYPE: UNITS:)	DESCRIPTION
0–5	SW	G					Reddish brown gravel with cobbles (fill).
5–15	GM						Light brown fine to coarse sand and gravel with cobbles, unconsolidated, medium dense, damp. (Colluvium/alluvium)
15–18	SM	D		2" SS	3"-50/140#		Reddish brown silty fine sand with fine gravel, dense, dry.
18–21	ML	D		2" SS	6"-25 6"-19		Tan/gray siltstone (Moenkopi Fm., bedrock).
21							TD 21'

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT
GRAVEL PACK: 16–30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

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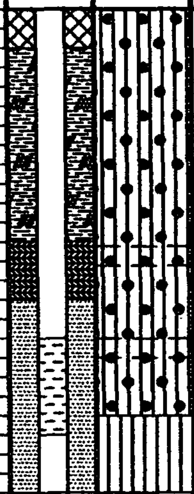
BORING/MONITOR WELL NO.: MW 3-5 **COMPLETION DATE:** 02/13/01
LOCATION: EAST POND #3
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW



DEPTH FEET	SOIL CLASS	SAMPLES: TYPE	SAMPLES: REC. %	SAMPLES: I.D./INT.	BLOW COUNT	SOIL ANALYSES (TYPE: / UNITS:)	DESCRIPTION
0–21	GM						Light brown fine to coarse sand and gravel with cobbles, unconsolidated, medium dense, dry. (Colluvium) Grading with thin (6") sand layers
10		D		2" SS	6"-50/140		
16		G					
21–25	ML						Tan/gray siltstone (Moenkopi Fm., bedrock).
25		D		2" SS	6"-34 6"-24		TD 25'

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT
GRAVEL PACK: 16-30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 4-1 **COMPLETION DATE:** 02/8/01
LOCATION: SOUTHEAST CORNER POND #4 - ABOVE
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	WELL CONST.	GRAPHIC LOG	SOIL CLASS	SAMPLES TYPE	SAMPLES REC. %	SAMPLES I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0			GM	G					Fine to coarse sand and gravel with cobbles, (colluvium/alluvium), unconsolidated, moderately dense.
				G					
				G					
25			SW	D		1.5" SS	6"–12/140# 6"–15		Reddish brown fine to mediuim sand, some silt, damp.
			ML	D			6"–28 4"–50		Tan/gray siltstone (Moenkopi Fm., bedrock).
30									TD 30'

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT

▨ GRAVEL PACK: 16-30 COLORADO SILICA SAND
▤ ANNULAR SEAL (1): BENTONITE CHIPS
☒ ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 4-2 **COMPLETION DATE:** 02/9/01
LOCATION: SOUTHWEST CORNER POND #4 - ABOVE
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	SOIL CLASS	SAMPLES TYPE	REC. %	I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0	GM						Light brown fine to coarse sand and gravel with cobbles (Alluvium/colluvium), unconsolidated, moderately dense.
5		G					
15		G					
25	SW	D		1.5" SS	6"-12/140# 6"-8		Reddish brown fine to medium sand with gravel, moderately dense, damp.
30		D		1.5" SS	6"-11 6"-12		Grading more dense with some silt, damp, very dense.
35		D		1.5" SS	5"-50		
38	ML						Tan/gray siltstone (Moenkopi Fm., bedrock).
40		D		1.5" SS	3"-50		TD 40.3'

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE - 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC - 0.10 SLOT
GRAVEL PACK: 16-30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

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BORING/MONITOR WELL NO.: MW 4-3 **COMPLETION DATE:** 02/9/01
LOCATION: BETWEEN PONDS 4 AND 3, WEST END.
PROJECT NAME: OMG APEX **PROJECT NO.:** OMG-01
BORING TYPE: HSA **BORING DIAMETER:** 6.5 INCH **LOGGED BY:** DLW

DEPTH FEET	WELL CONST.	GRAPHIC LOG	SOIL CLASS	SAMPLES TYPE	SAMPLES REC. %	SAMPLES I.D./INT.	BLOW COUNT	SOIL ANALYSES TYPE: UNITS:	DESCRIPTION
0									Reddish brown fine sand and gravel with some silt, dense, uniform, damp. (Alluvium)
5			SW	D		1.5" SS	6"-15/140# 6"-20		
10			ML	G		1.5" SS	6"-12 6"-13		Gray/tan siltstone (Moenkopi Fm., bedrock).
15				D			6"-40		TD 15'
20									
25									
30									
35									
40									
45									
50									
55									
60									
65									
70									

WELL COMPLETION MATERIALS

SURFACE COMPLETION: CONCRETE – 1' BEVELED
CASING: 5" SQUARE SURFACE STICK-UP 2.5'
SCREEN: 2" OD SCH 40 PVC – 0.10 SLOT
GRAVEL PACK: 16-30 COLORADO SILICA SAND
ANNULAR SEAL (1): BENTONITE CHIPS
ANNULAR SEAL (2): BENTONITE/CEMENT

Table A-1

Monitoring Well Construction Details

Monitoring Well No.	Depth to Bedrock (Ft)	Well Screen Depth (Ft)	Total Depth (Ft)
MW 1 - 1	24	20 - 25	25.0
MW 1 - 2	29	13 - 18	30.0
MW 1 - 3	27	17 - 22	29.0
MW 1 - 4	33	28 - 33	36.0
MW 2 - 1	13	6 - 11	14.2
MW 2 - 2	20	16 - 21	25.6
MW 2 - 3	14	9 - 14	19.3
MW 3 - 1	25	20 - 25	30.0
MW 3 - 2	23	13 - 18	25.6
MW 3 - 3	22	18 - 23	28.0
MW 3 - 4	18	14 - 19	21.0
MW 3 - 5	21	18 - 23	25.0
MW 4 - 1	26	22 - 27	30.0
MW 4 - 2	38	33 - 38	40.3
MW 4 - 3	9	7 - 12	15.0

APPENDIX B

Soil Gradation Analyses

Drill Cuttings from Leak Detection Wells by JBR (analyses performed by OMG)

Sample I.D.	Tare (g)	gross wet wt (g)	net wet wt (g)	gross dry wt (g)	net dry wt (g)	% solids
MW 1-1 @20.0'	1556.1	1941.6	385.5	1915.8	359.7	93.3
MW 1-2 @15-20'	1550.8	2108.9	558.1	2055.3	504.5	90.4
MW 1-3 @20.0'	1544.0	1804.6	260.6	1782.3	238.3	91.4
MW 1-4 @30'	1536.0	2019.7	483.7	1960.4	424.4	87.7
MW 2-1 @ 10-10.5'	1554.6	2006.1	451.5	1971.2	416.6	92.3
MW 2-2 @ 20.0'	1551.8	1807.1	255.3	1779.7	227.9	89.3
MW 2-3 @10.0-13.0'	1542.9	1982.2	439.3	1957.7	414.8	94.4
MW 3-1 @24.5-25.5'	1565.3	2186.1	620.8	2142.3	577.0	92.9
MW 3-2 @20.0'	1546.8	2065.6	518.8	2005.1	458.3	88.3
MW 3-3 @20.6'	1556.3	2103.2	546.9	2015.3	459.0	83.9
MW 3-4 @15.0'	1551.1	1830.7	279.6	1821.3	270.2	96.6
MW 3-5 @15.0'	1565.5	1965.2	399.7	1962.4	396.9	99.3
MW 4-1 @25.0'	1536.2	2337.4	801.2	2324.4	788.2	98.4
MW 4-2 @35.0'	1544.3	2005.6	461.3	1972.3	428.0	92.8
MW 4-3 @10.0'	1542.0	2026.8	484.8	1992.8	450.8	93.0

Screen Analysis

MW 1-1 @20.0'

Screen size	360.94 grams on screen	% on screen
8 mesh +	147.72	40.93
20 mesh +	60.75	16.83
30 mesh +	27.40	7.59
40 mesh +	19.88	5.51
80 mesh +	31.50	8.73
100 mesh +	7.10	1.97
100 mesh -	65.84	18.24
	360.19	99.79

MW 1-2 @15-20'

Screen size	503.28 grams on screen	% on screen
8 mesh +	266.97	53.05
20 mesh +	130.67	25.96
30 mesh +	24.98	4.96
40 mesh +	14.37	2.86
80 mesh +	21.81	4.33
100 mesh +	4.07	0.81
100 mesh -	40.04	7.96
	502.91	99.93

MW 1-3 @20.0'

Screen size	238.63 grams on screen	% on screen
8 mesh +	85.93	36.01
20 mesh +	59.11	24.77
30 mesh +	13.06	5.47
40 mesh +	8.34	3.49
80 mesh +	16.77	7.03
100 mesh +	3.94	1.65
100 mesh -	50.78	21.28
	237.93	99.71

MW 1-4 @30'

Screen size	426 grams on screen	% on screen
8 mesh +	237.77	55.81
20 mesh +	58.06	13.63
30 mesh +	13.14	3.08
40 mesh +	8.73	2.05
80 mesh +	17.67	4.15
100 mesh +	3.92	0.92
100 mesh -	86.08	20.21
	425.37	99.85

MW 2-1 @ 10-10.5'

Screen size	416.34 grams on screen	% on screen
8 mesh +	74.06	17.79

MW 2-2 @ 20.0'

	235.56 grams on screen	% on screen
Screen size	105.86	44.94

20 mesh +	46.76	11.23
30 mesh +	15.39	3.70
40 mesh +	11.37	2.73
80 mesh +	36.89	8.86
100 mesh +	12.14	2.92
100 mesh -	218.72	52.53
	415.33	99.76

8 mesh +	47.95	20.36
20 mesh +	11.90	5.05
30 mesh +	7.16	3.04
40 mesh +	13.13	5.57
80 mesh +	2.89	1.23
100 mesh +	45.59	19.35
100 mesh -	234.48	99.54

MW 2-3 @10.0-13.0'

413.87	grams on	% on
Screen size	screen	screen
8 mesh +	115.28	27.85
20 mesh +	44.11	10.66
30 mesh +	15.15	3.66
40 mesh +	12.24	2.96
80 mesh +	34.99	8.45
100 mesh +	11.45	2.77
100 mesh -	180.23	43.55
	413.45	99.90

MW 3-1 @24.5-25.5'

575.57	grams on	% on
Screen size	screen	screen
8 mesh +	291.7	50.68
20 mesh +	103.73	18.02
30 mesh +	26.12	4.54
40 mesh +	18.01	3.13
80 mesh +	37.13	6.45
100 mesh +	7.95	1.38
100 mesh -	90.35	15.70
	574.99	99.90

MW 3-2 @20.0'

458.99	grams on	% on
Screen size	screen	screen
8 mesh +	264.74	57.68
20 mesh +	89.21	19.44
30 mesh +	19.33	4.21
40 mesh +	12.08	2.63
80 mesh +	20.40	4.44
100 mesh +	3.66	0.80
100 mesh -	48.68	10.61
	458.10	99.81

MW 3-3 @20.6'

467.98	grams on	% on
Screen size	screen	screen
8 mesh +	202.20	43.21
20 mesh +	56.86	12.15
30 mesh +	13.40	2.86
40 mesh +	8.56	1.83
80 mesh +	17.98	3.84
100 mesh +	11.74	2.51
100 mesh -	156.79	33.50
	467.53	99.90

MW 3-4 @15.0'

269.91	grams on	% on
Screen size	screen	screen
8 mesh +	108.07	40.04
20 mesh +	21.07	7.81
30 mesh +	6.52	2.42
40 mesh +	5.89	2.18
80 mesh +	27.44	10.17
100 mesh +	12.32	4.56
100 mesh -	87.76	32.51
	269.07	99.69

MW 3-5 @15.0'

402.96	grams on	% on
Screen size	screen	screen
8 mesh +	277.86	68.95
20 mesh +	36.24	8.99
30 mesh +	8.64	2.14
40 mesh +	6.43	1.60
80 mesh +	18.14	4.50
100 mesh +	4.99	1.24
100 mesh -	49.91	12.39
	402.21	99.81

MW 4-1 @25.0'

702.61	grams on	% on
Screen size	screen	screen
8 mesh +	278.89	39.69
20 mesh +	234.93	33.44

MW 4-2 @35.0'

428.24	grams on	% on
Screen size	screen	screen
8 mesh +	216.61	50.58
20 mesh +	90.02	21.02

30 mesh +	51.78	7.37
40 mesh +	28.62	4.07
80 mesh +	35.65	5.07
100 mesh +	4.87	0.69
100 mesh -	67.34	9.58
	702.08	99.92

30 mesh +	18.84	4.40
40 mesh +	11.71	2.73
80 mesh +	20.42	4.77
100 mesh +	4.26	0.99
100 mesh -	66.03	15.42
	427.89	99.92

MW 4-3 @10.0'

Screen size	447.21	**grams on screen**	**% on screen**
8 mesh +		161.34	36.08
20 mesh +		76.48	17.10
30 mesh +		23.4	5.23
40 mesh +		18.16	4.06
80 mesh +		41.62	9.31
100 mesh +		9.55	2.14
100 mesh -		116.01	25.94
		446.56	99.85

Apex Site

Engineering Report
for
Pond 2 Final Closure

Prepared for:

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1.0 INTRODUCTION

This report presents the Final Closure Plan for reclamation of Pond 2 at Hecla Mining Company's Apex Site near St. George, Utah. The closure plan, when implemented, is designed to provide for long-term hydraulic isolation of wastes currently contained in Pond 2 (the impoundment). Six closure plan alternatives were analyzed by Monster Engineering Inc. (MEI 2003a) and reviewed by Hecla prior to selection of a Selected Alternative for implementation. Details of the Selected Alternative, and one Modified Alternative, are presented as the Final Closure Plan in this document.

This Final Closure Plan is presented in two volumes. Volume I (this volume) is organized in five sections, including this Introduction section, that describe and summarize the closure plan, along with all Tables, Figures and the Appendices. Section 2.0 describes site background, and includes summaries of previously conducted waste material sampling and analysis, and the potential borrow material investigation. Additional waste material and field investigation information is included in Appendices A and B. Descriptions of the various closure alternatives examined, including Hecla's Selected Alternative, are presented in Section 3.0, Closure Alternatives. Section 4.0 presents the estimated construction sequencing and Section 5.0 summarizes design analyses for the Selected Alternative. Section 6.0. provides a construction cost estimate. Tables and Figures referenced in each section are presented at the end of the report. Complete analyses for the Selected Alternative are included in Appendices C through F. Estimated construction costs, the Monitoring and Maintenance Plan, and the Quality Control Plan are included in Appendices G, H, and I, respectively. Volume II of this plan contains the Final Plan Specifications and Drawings.

2.0 SITE BACKGROUND

The Apex Site is located approximately 15 miles northwest of St. George, Utah (Figure 1) on land leased from the Shivwits Band of the Paiute Tribe. The project location is shown on Figure 2. Pond 2 (the impoundment) is a synthetically-lined waste containment facility approximately 500 feet in diameter and 15 feet deep (SMI 2001). The current bottom liner consists of a fabric-reinforced spray-on asphaltic membrane approximately one-quarter to one-half inch in thickness. Hecla removed and disposed of a variety of on-site materials into Pond 2 as part of a site cleanup agreement with OMG in 1995. Materials currently in the impoundment include:

- gallium and germanium extraction process wastes (solutions and solids)
- cobalt-sulfate recovery process wastes
- ore stockpile materials
- old impoundment liner materials
- subsoils

Some of these materials were mixed with lime and limestone prior to disposal, while others were dredged and pumped into the impoundment as a slurry. During site cleanup work, the perimeter embankment was raised approximately five feet to provide sufficient capacity for waste material disposal. The embankment raise was constructed utilizing on-site soils (clay to cobble sizes) over the centerline of the existing embankment. The raise was unlined and the crest is approximately 10 feet wide. The embankment ranges from three feet to seven feet above the existing ground surface with outslopes that range from approximately 2:1 (H:V) to 3:1. Currently the impoundment has a temporary cover which is approximately two to four and one-half feet thick. It was constructed of a combination of on-site materials ranging from rock to topsoil. After completion of the temporary cover several seepage areas developed through and at the outside face of the unlined embankment raise. Figures 3 and 4 show the plan view and two profiles of the current impoundment configuration. Information provided in Figures 3 and 4 was collected by Hecla during prior reclamation activities (SMI 2001 and Hecla 2001) and field investigations. These prior field investigations are discussed in Sections 2.1 and 2.2.

The impoundment is underlain by up to 30 feet of aeolian and colluvial soils, primarily silty sands. Beneath these soils are a sequence of sandstones, siltstones, and limestones several hundred feet thick. Groundwater levels have been measured at depths from 160 to 300 feet (SMI 2001).

The Apex Site is located in a very arid region, averaging between 8.3 and 12.5 inches of precipitation annually. Surface water drainage at the site area is in general from south to north. All current upgradient runoff is diverted to the north on the east side of the impoundment by a small diversion channel. The limited quantity of runoff from the temporary cover (top surface of the impoundment) generally collects at the toe of the existing embankment in a separate broad flat collection ditch / basin. It appears that most, if not all impoundment runoff remains in this basin, however some minor quantities may flow to the north around both sides of the impoundment.

During 2001 and 2002 Hecla completed two separate field investigations and laboratory analyses of the waste materials and potential borrow materials. Physical properties of representative materials were determined for utilization in the Final Closure Plan alternatives analyses.

2.1 Waste Material Sampling and Analysis

In October 2001 Hecla conducted a drilling, sampling, and laboratory testing program to determine the extent of, and potential for, seepage migration from the impoundment (Hecla 2001). Eight relatively undisturbed samples of waste materials from within the impoundment were successfully collected from depths ranging from five to nine feet below the top of the current surface. Wastes sampled were those from the last layer placed prior to temporary cover construction.

Moisture contents of the sampled waste materials ranged from 20% to 116% and in general increased with increasing depth and distance away from seepage areas. Seepage areas are shown on Figure 3. Additionally, the wastes were generally very fine grained with between 36 and 99 percent passing the #200 sieve. Laboratory permeability of the one tested sample was 3.7×10^{-6} cm/sec, indicating that seepage rates through the waste materials have been, and without assistance from installed drains, will continue to be very slow. All waste material laboratory test results are summarized in Appendix A.

The two known embankment seepage areas in general correlate with locations where coarser materials are known to have been placed during disposal and temporary cover placement activities. Profiles shown in Figure 4 show approximate waste material type locations (depths), sample locations, and sample moisture contents. As Hecla did not want to damage the bottom liner during drilling and sampling activities, and there is some uncertainty as to the actual liner elevation (depth), Material Types I through III were not sampled during the investigation. Therefore, moisture contents of material Types I through III are currently unknown. It is known that Material Type I included tailings and Material Type II included materials pumped into the impoundment as slurry (SMI 2001). Moisture contents of these materials may therefore be relatively high, although they have been and continue to be under much greater consolidation pressure than Material Type IV.

Two conclusions from the October 2001 materials investigation were:

- ➢ the collection ditch and evaporation ponds located on the southwest side of the impoundment are working properly and there is no evidence of seepage migration into soils outside the impoundment area near the southwestern seep or downgradient of the impoundment
- ➢ waste materials within the impoundment are very heterogeneous

2.2 Potential Borrow Source Materials Investigation

In November of 2002 Hecla conducted a potential borrow source materials investigation at and near the site to identify potential sources, available quantities, ownership, and index properties of suitable borrow materials (MEI 2003b). The physical properties of soils from these potential sources were utilized in the development of the Final Closure Plan alternatives.

Material properties of each layer in a cover system are critical to the long-term success of the overall cover (see Section 3.2 for general descriptions of cover systems and layer names). The Barrier Layer is the critical component of any cover system, therefore locating suitable materials for that layer was determined to be a key step in the design process. Suitable borrow materials were those which under optimum moisture and compaction conditions would exhibit a generally low permeability (1×10^{-6} to 1×10^{-8} cm/sec). The main conclusion from the field investigation was that several suitable low permeability borrow materials, in quantities sufficient to provide for a final cover for the impoundment, were located both near the site and on-site. Complete results from the field investigation and laboratory testing program are included in Appendix B.

3.0 CLOSURE ALTERNATIVES

Part of the process of implementing an effective and economic closure plan for Pond 2 included examining and analyzing three different waste drainage / consolidation methods and six different cover system alternatives. Analyses were conducted by Monster Engineering, Inc. (MEI 2003a) and reviews were completed by Hecla. One drainage / consolidation method and one cover system alternative were selected by Hecla as the Selected Alternative for this Final Closure Plan. Discussions regarding waste drainage / consolidation objectives, methods, and analyses, and the selected method are included in Section 3.1. Cover system background information, along with a summary of the different cover systems analyzed is included in Section 3.2. Details of the Selected Alternative's cover system are discussed included in Section 3.2.3. An additional cover system alternative (the Modified Alternative) was also selected by Hecla and is included in this plan (Section 3.2.4). The Modified Alternative was selected as a backup to allow Hecla some flexibility during the bidding and construction phase of the plan. In summary, the Modified Alternative consists of changing the Barrier Layer from a Geosynthetic Clay Liner (GCL) to a compacted clay liner (CCL). The CCL would be constructed with materials from a nearby native clay source (Blue Clay from the St. George area).

3.1 Waste Material Drainage and Consolidation

The primary objective of all cover systems is to provide for long-term hydraulic isolation of wastes. Too much differential or long-term consolidation after a cover system is completed can breach a cover system (EPA 1998). Therefore, a main factor in designing and constructing a successful cover system is to drain and consolidate wastes (and minimize future cover settlement) prior to cover system completion. Due to the physical characteristics of wastes within Pond 2, the potential for large differential and / or total long-term consolidation after placement of the cover system is significant. Waste characteristics include:

- high moisture contents
- high percentage of fines (very slow drainage)
- significantly varied material types and placement / disposal techniques
- relatively large consolidation force which will be applied by the final cover system
- potential continued seepage migration, similar to past seepage migration, towards the impoundment's unlined embankment raise

Relatively rapid and thorough drainage and consolidation of wastes prior to final cover placement should:

- remove and allow for evaporation of excess liquids currently within the wastes
- minimize overall and potentially large differential settlements after final cover completion
- minimize potentially expensive cover system repairs
- shorten the overall cover system construction period
- minimize hydraulic head on the existing bottom liner
- minimize future seepage towards and through the existing embankment and / or the tie-in between the cover system and existing liner

The drainage and consolidation methods reviewed and analyzed for the Closure Plan were in general based on three design criteria, which if implemented, would remove remaining free water from the wastes. (Hecla 2001). Those criteria were that the drainage system should:

- ➢ be passive and rely on gravity to convey flows
- ➢ incorporate existing evaporation ponds at the southwest embankment toe
- ➢ increase the consolidation rate of waste materials and removal of remaining free water

In order to meet the above criteria, three drainage and consolidation techniques were considered:

(1) vertical wick drains
(2) horizontal drains
(3) no drains (weight of final cover only)

Hecla selected the vertical wick drain method based on analysis of the waste characteristics, the impoundment setting, overall cost, and potential effectiveness. In particular, the vertical wick drain method was selected because it could:

- ➢ be less time consuming to install versus horizontal drains
- ➢ provide for more thorough and timely drainage of all waste materials by providing the shortest drainage path - close spacing and uniform installation depth to reach all areas of the impoundment
- ➢ effectively reach most wastes - all areas of the impoundment can be easily reached from the surface
- ➢ be the most effective method of controlling and evaporating draining liquids by containing those liquids on top of the temporary cover - no additional collection ditches or evaporation ponds required and no additional pumping or monitoring required
- ➢ allow for quicker removal and disposal of existing Collection Ditch and Evaporation Pond materials
- ➢ allow for less complicated tie-in construction between the existing bottom liner and the new (GCL) top liner
- ➢ allow for more efficient construction sequencing
- ➢ more effectively reduce hydraulic head on the existing bottom liner

3.2 Cover Systems

3.2.1 Background Information

Cover systems can range from a one-layered vegetated soil to a complex multi-layer approach utilizing soils and geosynthetics (EPA 1998). Their effectiveness is primarily a function of the attention given to quality in choosing, installing, and inspecting each layers' materials and placement techniques (Daniel 1995a). Covers are also most effective where wastes are placed above the groundwater table, as is the case for Pond 2. In general, less complex systems are required in arid climates and more complex systems are required in wet climates. Although designs vary significantly from site to site, the basic layout of a multi-layered cap is summarized from top to bottom in Table 1 (EPA 1993). In this table each layer of a typical cover system is listed along with its primary functions, construction materials, and general considerations given the waste material characteristics within the impoundment and site specific considerations.

The design of each cover system is site-specific and depends on the intended functions. The following functions were considered crucial for the Pond 2 cover system analyses and were used as a starting point for examining alternatives:

- Provide for high resistance to cover damage by impacts due to total long-term and differential waste settlement.
- Minimize surface water infiltration.
- Minimize long-term seepage generation.
- Prevent / limit seepage migration.
- Minimize surface erosion by controlling runoff.
- Provide for efficient site drainage and route surface water away from the impoundment.
- Minimize post-closure cover maintenance requirements and costs.
- Provide for sufficient final cover interface stability especially on embankment outslopes.

The following cover system functions are also considered during the design phase, but were not of immediate concern at Pond 2 based on the physical nature of the wastes contained:

- leachate management - currently being successfully managed by a lined Collection Ditch and Evaporation Ponds
- gas management - not a concern due to non-gas producing nature of waste materials

The most critical component of any cover system, in respect to selection of materials, is the Barrier Layer. It can consist of either a GCL, a low-permeability CCL, or a geomembrane (such as VLDPE or HDPE). GCL's are typically composed of a thin layer of processed bentonite sandwiched between two geosynthetic materials although other configurations are available. The bentonite expands to create the low-permeability barrier (typically between 1 and 5 x 10^{-9} cm/sec) that is self-healing. GCL's are either non-reinforced (adhesive bond between the bentonite and the synthetics) or reinforced (needle-punched) (Daniel 1995) (EPA 1995).

CCLs are only effective if they retain a certain moisture content and if differential settlement is very limited. CCLs are susceptible to cracking if the liner material dries out during or after construction, which is a concern in the arid St. George climate. In arid climates, GCLs are a better overall choice than CCLs for final covers because GCLs can better resist wet-dry cycles, freeze-thaw conditions, and differential settlement (Daniel 1995b). Thin membranes (geomembranes and GCLs) are more vulnerable to construction damage or post-construction puncture. Table 2 summarizes the relative advantages and disadvantages of the three types of Barrier Layer materials.

The next layer above the Barrier Layer, in an arid climate cover system design, is the Protection Layer. It protects underlying layers from dessication, freezing and thawing, and animal and root intrusion. It also helps maintain stability and provides for storage of infiltration water. In arid climates it may be important to cover the Protection Layer with a Surface Layer to protect the cover system from erosion due to both wind and surface water runoff as it can be difficult for vegetative growth to reestablish. If necessary, the Surface Layer typically consists of well graded gravel / rock / cobble mixtures designed to withstand erosive surface water and runoff forces. The Surface Layer also protects underlying layers from intrusion and promotes evapotranspiration.

3.2.2 Summary of Closure System Alternatives Analyzed

The cover system alternatives considered for the Apex Site consisted of six different designs, each of which could, if properly constructed, provide hydraulic isolation for wastes by:

- preventing or minimizing downward flow of precipitation inside and immediately next to the impoundment area
- performing effectively over the long-term without being damaged by characteristics of the underlying waste or erosion effects due to wind or surface water runoff

Table 3 (Final Closure Plan Alternatives) provides a summary of all layers in each cover system alternative analyzed and provides a range of estimated construction costs (no QA/QC or CM costs included). Each cover system design was based on analyses of many different variables and construction requirements. Each system has been successfully constructed at other waste facilities. The variables and requirements considered and used in the analyses are listed below in general order of importance:

- standard and acceptable designs for multi-layered cover systems as detailed by the EPA (EPA 1993, 1995 and 1998)
- physical setting of existing impoundment, embankment, and wastes
- methods for waste drainage and consolidation
- climate
- overall cover system effectiveness
- estimated construction cost
- constructability
- containment of waste / cover system tie-in to existing liner
- material availability (on-site, off-site, and synthetic)
- potential borrow soil permeability
- long-term erosion protection
- cover system slope / surface drainage

3.2.3 Alternative 2 (GCL) - Selected Alternative Cover System

Based on the overall objectives for the Pond 2 cover system and the variables and requirements as listed in the previous section, Hecla selected Alternative 2 (designated as the GCL alternative) as the optimal cover system for the impoundment. Alternative 2 consists of a three layer cover system which will, if properly constructed, provide hydraulic isolation for the wastes and perform effectively over the long-term. The three layers consist of from top to bottom:

(1) Surface Layer
(2) Protection Layer
(3) Barrier Layer (GCL).

A Drainage Layer is not required due to arid climate and a Gas Collection Layer is not required as the wastes do not produce any gasses.

The basic design elements of the GCL Alternative are:

- vertical wick drains
- 1% final top slope
- reconstructed and GCL lined impoundment embankments with 3.5:1 (H:V) outslopes
- Surface Layer - 2 inch thick layer of D_{50} = 1 inch rock on the impoundment outslopes
- Protection Layer - 12 inches of low permeability (2.6×10^{-6} cm/sec) on-site soils (designated as TP-1 material)
- Barrier Layer - GCL with permeability of 1 to 5×10^{-9} cm/sec
- widened diversion channel on the east side of the impoundment with erosion protection along the impoundment embankment

There were several compelling reasons why Alternative 2 (GCL) was preferable to other alternatives analyzed including:

- no cost to purchase and ship on-site (TP-1) soils (utilized for the Protection Layer)
- final permeability of TP-1 soils are not an issue (other alternatives utilized TP-1 soils for the Barrier Layer)
- Barrier Layer constructed of GCL which is highly reliable, easy to obtain, very rapid to install, and less susceptible to damage if differential settlement of the wastes does occur
- minimal QA/QC required during GCL installation compared to other alternatives

Potential drawbacks to Alternative 2 are:

- could be the third most expensive cover system to construct ($240,000 to $400,000)
- stability on the embankment sideslopes could be a concern due to low interface friction between GCL (if bentonite becomes hydrated) and underlying / overlying materials
- potential insufficient quantity of TP-1 soils

Figure 5 shows the design profile for this alternative. Appendix C contains results from HELP model / seepage analyses for this alternative.

3.2.4 Modified Alternative Cover System (Blue Clay)

A Modified Alternative, selected by Hecla, is included in this Final Closure Plan to allow for some flexibility during bidding and construction phase of the project. The modification from the Selected Alternative consists of replacing the GCL Barrier Layer with a compacted clay liner (CCL). The CCL would be constructed with materials from nearby clay sources (Blue Clay from the St. George area). This Modified Alternative is Alternative 1 in Table 3 (designated as the Blue Clay alternative). The remaining design elements of this Modified Alternative are identical to Alternative 2 (GCL).

This alternative has potential positives and negatives similar to Alternative 2 except that it could potentially be the least expensive cover system to construct ($190,000 to $310,000). Potential drawbacks to this alternative include:

- Blue Clay is only available in a piece-meal fashion as it is typically excavated from the foundation areas of smaller construction sites in and around St. George
- make-up water would be required for processing and during placement of the Blue Clay Barrier Layer

Complete estimated construction costs for both the Selected Alternative (GCL) and the Modified Alternative (Blue Clay) are included in Section 5.0. Appendix C contains results from HELP model / seepage analyses for the Modified Alternative.

3.2.5 Additional Cover System Alternatives Analyzed

Four additional cover system alternatives were analyzed but not selected for the Final Closure Plan. Those alternatives, listed as Alternatives 3 through 6 in Table 3, were rejected from further consideration due to one or more of the following:

- prohibitively high construction costs
- significant potential for long-term and expensive maintenance / repairs
- locally available and acceptable borrow materials
- design that was more stringent than required - equally effective hydraulic isolation obtainable with significantly lower cost

Alternative 3 (On-Site Materials I) utilized on-site and off-site materials (TP-1 and Shivwit's Dam) for the Protection Layer and on-site materials (TP-1) for the Barrier Layer. It was rejected from further consideration due to the availability of less expensive and more reliable Barrier Layer materials. Both the GCL and Blue Clay (CCL) would be cheaper to install / process and place, would require significantly less processing water, and would provide for more effective long-term hydraulic isolation.

Alternative 4 (VLDPE / HDPE) included a geomembrane Barrier Layer in the design. It was included in the analyses as a potential alternative in case nearby, cost effective, and acceptable borrow soils for cover construction could not be located. As this was not the case, this alternative was rejected. This alternative also had the potential for more expensive construction and damage to the geomembrane during and / or after construction.

Alternative 5 (RCRA Type) was included in the analyses for cost comparison only. Its design was similar to a typical multi-layered RCRA cover utilized for hazardous wastes. It was eliminated from consideration as it was more stringent than required at this site, and it would be prohibitively expensive to construct (two to three times more expensive than the Selected Alternative and similarly effective cover system).

Alternative 6 (On-Site Materials II) would likely have been the least expensive to construct at an estimated cost of $90,000 to $150,000. However, as no drains were included in this alternative, it had the highest potential for expensive long-term maintenance and repairs due to differential settlements which would likely have occurred after completion of construction. Additionally, this alternative was eliminated from consideration due to

- requirement of additional fill placement (to 2%)
- greater damage potential due to the lack of an erosion protection layer

4.0 CONSTRUCTION SEQUENCE FOR SELECTED ALTERNATIVE

4.1 Overview

The objective of this Final Closure Plan is to drain and consolidate the existing wastes, prevent future seepage through the existing embankment, dispose of all existing Collection Ditch and Evaporation Pond materials, and hydraulically isolate for the long-term all wastes within Pond 2. The Final Closure Plan will consist of implementing Alternative 2 (GCL) as detailed in the following sections. In general, final closure construction activities will include the following three phases:

- Phase 1 Drainage and Consolidation
- Phase 2 Impoundment Regrading
- Phase 3 Final Cover System Construction

Individual construction steps required to complete each phase are discussed in greater detail in Sections 4.2, 4.3 and 4.4.

4.2 Phase 1 - Drainage and Consolidation

During Phase 1 free liquids within the waste materials will be sufficiently drained and evaporated, allowing the wastes to consolidate. Settlement of the top surface of the impoundment will be measured. Liquids emitting from the waste materials / wick drains will be managed to maximize evaporation rates and minimize construction time. Due to very high evaporation rates in this area, it is estimated that very little liquid will exist on the surface at any given time during this phase. When it has been determined that overall settlement has slowed to an acceptable rate, that is a rate at which additional settlement will not compromise the long-term integrity of the overall cover system, then construction of the final cover system can begin. Once seepage towards and through the existing embankment has decreased sufficiently, the Collection Ditch and Evaporation Pond materials will be removed and buried within the impoundment. Organizationally, Phase 1 is broken into the following six steps:

- Temporary Berm Construction
- Settlement Monument Installation
- Vertical Wick Drain Installation
- Drainage and Consolidation
- Liquid Evaporation
- Collection and Evaporation Pond(s) Removal and Disposal

Details for each step of Phase 1 are included in the sections below.

4.2.1 Temporary Berm Construction

Existing temporary cover materials will be utilized to construct a small containment berm along the outside perimeter of the impoundment and into berms which divide the top surface of the impoundment into approximately 30 foot by 30 foot cells. The individual cells will enhance evaporation rates and allow for simpler management of liquids draining from the vertical wicks and liquids pumped from the existing Collection Ditch and Evaporation Ponds. The perimeter berm will be constructed approximately 20 to 30 feet back from the impoundment crest. Berms will be approximately one foot in height and constructed out of existing temporary cover materials. Compactive effort will be applied as necessary to minimize seepage between cells and potential berm failure.

4.2.2 Settlement Monument Installation

Settlement monuments will be installed at approximately six to eight locations into the top surface of the impoundment to monitor settlement which occurs after installation of the wick drains. Monuments will consist of vertical "stand pipes" attached to metal base plates. The base plates will be buried to a depth of approximately one to two feet into the temporary cover (for protection) and the stand pipes will extend approximately four to five feet above the ground surface. Initial baseline measurements will be collected prior to construction activities (drain installation). It is estimated that surveys will then be collected approximately every week for approximately four to six weeks, at which time it is estimated that the consolidation rate will have slowed to a point where final cover system construction can begin. Survey frequency will be adjusted as needed to accurately determine the consolidation rate.

4.2.3 Vertical Wick Drain Installation

Vertical wick drains will be installed through the temporary cover materials (if possible) and to within one to two feet of the existing bottom liner. These drains will provide a conduit for liquid flow to the surface of the impoundment. A typical wick drain consists of a prefabricated, flexible, polypropylene drain core surrounded by a strong, durable, non-woven polypropylene geotextile filter jacket. The jacket filter allows passage of fluids into the drain core while preventing piping of fines. It also helps to maintain the core shape and hydraulic capacity of the core channels. Figure 6 contains details on the materials, installation, and consolidation method with vertical wick drains.

Vertical wicks are typically installed utilizing a modified excavator that includes a structural mast. The hydraulics drive a mandrel, an anchor plate, and the attached end of the wick into the ground to the desired depth. The anchor plate prevents waste materials from entering and clogging the mandrel and it anchors the wick in place at the desired depth as the mandrel is being retracted. After the mandrel is withdrawn, the wick is cut off above the ground surface, the mast is moved to the next location, and the process is repeated. If drains can not be installed through the temporary cover materials due to large rocks and cobbles, then the driving unit will be moved laterally several feet and another attempt will be made. If it is still not possible to push through the temporary cover materials, a backhoe will impoundment into approximately 30 foot by 30 foot cells. The individual cells will enhance evaporation rates and allow for simpler management of liquids draining from the vertical wicks and liquids pumped from the existing Collection Ditch and Evaporation Ponds. The perimeter berm will be constructed approximately 20 to 30 feet back from the impoundment crest. Berms will be approximately one foot in height and constructed out of exis Compactive effort will be applied as necessary to minimize seepag failure.

– may not be enough time for consolidation; (4-6 wks)?
– why not "until consolidation has stopped" or some such language.
– App D – say's 2 months to consolidate!! Discrepancy

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They should wait until consolidation is nil !!

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4.2.4 Drainage and Consolidation

After installation of the wick drains, fluid should begin to flow to the surface where it will evaporate, and if necessary be retained by the temporary berms. Additional loading will be added to the top surface, after installation of the perimeter vertical wick drains, to enhance and speed up drainage and consolidation, especially near the perimeter of the impoundment. This additional loading will consist of materials selectively excavated from the existing embankment resloping work discussed in Section 4.4.1 below. The availability and application this material will be dependent on the effectiveness of wick drains installed near the impoundment perimeter, the overall stability of the resloped embankment as construction proceeds, and the weather during this phase of construction (amount of precipitation and evaporation rate). This material will also provide the needed material for resloping the top surface to an overall 1% grade.

?

Overall settlement of each monument will be monitored and settlement rates will be calculated to verify when acceptable rates of consolidation have been reached. Due to the heterogeneity of the waste materials, it is likely that each area of the impoundment will produce different amounts of liquids, will experience varying amounts of settlement, and that acceptable settlement rates will be reached at different times. Acceptable settlement rates will be dependent on the location within the impoundment, and will in general be that rate at which it is determined that additional settlement will not compromise the long-term integrity of the overall cover system. Once an acceptable rate has been reached, and all retained fluids have been removed (evaporated or moved to another portion of the impoundment) then construction of the final cover system in that area of the impoundment can begin.

How?

4.2.5 Liquid Evaporation

Fluids exiting the vertical wick drains, and fluids from the Evaporation Ponds and Collection Ditch will be retained on the top surface of the impoundment by the temporary berms discussed in Section 4.2.1 above. Fluids from the Evaporation Ponds and Collection Ditches will be pumped into the cells. Fluids within the cells will be managed depending on quantities produced, cell holding capacity, and overall weather conditions. As needed, fluids may be pumped from one cell to another to enhance evaporation rates and accelerate the overall construction process. In order to provide for a more stable outside embankment, decrease the potential for fluids in the temporary cover materials near the perimeter of the impoundment, and prepare for Phase 2 regrading work (Section 4.3), fluids will likely be pumped into cells nearer the center of the impoundment.

be utilized at that particular location to excavate a small opening through the temporary cover to a depth where the wick drain can be pushed. Estimated horizontal spacing between the drains will be between 3.4 and 5.4 feet. Appendix D contains the vertical wick drain analyses which is based on data collected from the October 2001 waste material drilling and sampling program (MEI 2002).

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"Acceptable rate of consol. should be when there is virtually 'NO' consol." -This language should be Δed to state that, or to ↓ 1cm/mnth etc.

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- Or, it could be based on the Geotextile CL manufacturers; acceptable ~~spec~~ specs.

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4.2.6 Collection Ditch and Evaporation Pond Removal and Disposal

Seepage flow into the Collection Ditch and Evaporation Ponds will continue to be monitored after construction has begun. Once flow has either decreased to a point when it is not causing stability problems, or when it has stopped altogether, the Collection Ditch and Evaporation Pond materials will be removed and buried within the impoundment. Any other obviously contaminated materials encountered during this process will also be excavated and placed within the impoundment. All materials excavated during this step will, if possible, be buried beneath the current temporary cover.

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use this.

4.3 Phase 2 - Impoundment Regrading

During Phase 2 most of the existing impoundment perimeter embankment will be removed and utilized as additional loading and temporary cover material for the impoundment's top surface. Depending on the amount of fluids produced through the wick drains and the evaporation rate (fluid management and weather), this phase will most likely be incremental, with certain areas of the impoundment accessible sooner than others. The objective of the regrading phase is to achieve approximate final impoundment configurations prior to construction of the final cover system (Phase 3).

4.3.1 Existing Embankment Resloping

A significant portion of the impoundment's existing perimeter embankment will be excavated and utilized as loading on the top surface to:

- increase vertical wick drainage
- increase waste material consolidation rates
- achieve the impoundment's overall top slope of approximately 1% (post drainage and consolidation)
- allow space for reconstruction of a more suitable perimeter embankment
- allow space for construction of a tie-in between the existing impoundment liner and the final cover system Barrier Layer (GCL)

The outslope of the current perimeter embankment varies from approximately 2:1 (H:V) to 3:1. The final re-constructed embankment will have an outslope of approximately 3½:1. During excavation the existing embankment will be cut back to approximately a 1:1 slope. Figure 7 shows a typical profile of the existing embankment, impoundment liner, the portion of that embankment which will be removed, and the temporary perimeter berm which will be constructed to retain potential surface fluids during evaporation (Phase 1). Figure 8 shows a typical profile at the same location after selective removal of a portion of the embankment. As the excavated embankment will be steeper than the existing embankment, a slope stability analysis was conducted on the excavated embankment to determine an approximate factor of safety (F.O.S.). That analysis shows that the excavated embankment will be stable based on measured and correlated material strength values, and existing

- final construction should not continue until the fluids in the - seepage area, cease to flow

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- achieve the impoundment's overall top slope of approximately 1% (post drainage and consolidation)
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If during, or after, removal of portions of the existing embankment, unacceptable quantities of seepage occurs at the perimeter, potential solutions will include minor additional excavation, construction of a temporary clay or GCL covered berm, and / or pumping of excess fluids to the top of the impoundment. If a temporary clay or GCL covered berm is required, it would be tied into the existing impoundment liner to provide for any potential seepage containment. Once any unacceptable seepage stops and remaining liquids are removed, final cover surface grading can be completed and final cover system construction can begin (Section 4.4).

4.3.2 Final Cover Surface Grading

After fluids (if any) on top of the impoundment have evaporated sufficiently to allow for construction equipment to access the surface, settlement has slowed to an acceptable rate, and existing embankment materials have been excavated and placed on top of the impoundment, the top surface will be graded to create an approximate one percent (1%) slope down towards the perimeter of the impoundment, with a starting center elevation of 3,683 feet. Depending on condition and quantity of available existing embankment materials, overall quantities of settlement of the waste materials, and overall condition of the top surface of the impoundment, additional soils may be placed to achieve the final slope. These additional soils may be on-site or off-site materials depending on their availability and cost.

4.4 Phase 3 - Final Cover System Construction

The objective of Phase 3 will be to complete the final cover system. This will consist of placing the three final cover system layers, excavating / constructing and installing erosion protection for the surface water diversion channel, reconstructing the impoundment embankment.

4.4.1 Barrier Layer Placement

The Barrier Layer will be placed directly on top of the final regraded surface which will be smooth and free of all materials such as large stones, stakes, and other potentially damaging materials. The Barrier Layer material will consist of a GCL such as Bentofix, Bentomat, or Claymax. The GCL's specified will be composed of a thin layer of processed bentonite sandwiched between two geosynthetic materials. When exposed to moisture the bentonite expands to create a low permeability barrier (typically 5×10^{-9} cm/sec) that is self-healing for holes up to 75 millimeters. A non-reinforced GCL such as Claymax 200R will be specified for the top surface of the impoundment where internal shear strength is not a concern due to the relative flatness of the slope. A reinforced needlepunched

GCL with higher internal shear strength such as Bentomat ST or Bentofix Thermo Lock will be specified for the impoundment outslopes as they are significantly steeper than the top surface. Figures 9 and 10 show details on how the GCL will be tied into the existing impoundment liner and into the native soils outside of the impoundment.

4.4.2 Protection Layer Construction

The Protection Layer will be placed directly on the Barrier Layer and will consist of native materials (designated as TP-1) excavated from the southeast, east, and northeast sides of Hecla's property immediately adjacent to the impoundment. Based on the November of 2002 field investigation and laboratory test results, these soils consist mainly of sandy lean clays with a permeability of approximately 2.6×10^{-6} cm/sec. In order to provide sufficient material for this layer, a fairly significant borrow area will be excavated between the impoundment and Hecla's fence line. Utilization of this area as a borrow source will allow for a wider and more gently sloping diversion channel that is located further from the toe of the impoundment than the existing diversion channel. The larger diversion channel will provide for much improved long-term erosion protection for the impoundment embankment. Figures 11 and 12 show a plan view and two profiles of the borrow area / diversion channel.

Also included in this step is the reconstruction of the impoundment embankment. Several materials are suitable and available for use including those mentioned above (TP-1) and the Blue Clay which is locally available in the St. George area. Final material selection will depend on available quantities and purchase and placement costs. Figure 13 shows a profile of the reconstructed embankment including details on the liner tie-in and the final cover system configuration as it is constructed over the liner tie-in.

4.4.3 Surface Layer Placement

The Surface Layer will be placed on top of the Protection Layer. It will be the last layer of the cover system and will serve as erosion control on the impoundment outslopes. Storm water runoff and erosion protection analyses show that erosion protection larger than what will be the already in-place Protection Layer is not necessary on top of the impoundment. The same analyses show that the required erosion protection on the impoundment outslopes will consist of a two inch thick layer of well graded rock which has a D_{50} of one (1) inch. The design event for these analyses was 6-hour, 25-year event. Storm depth of this event was 1.9 inches. Appendix F contains all runoff and erosion protection material sizing calculations.

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-They should go ahead to put the "surface layer" on top of the "protection" layer on the top of fill, Not only the sides. It should be designed for more than a one in 25 yr. Storm event

4.4.4 Diversion Channel Erosion Protection Placement

Runoff and erosion protection sizing analyses were also conducted on the diversion channel immediately adjacent to the impoundment. These analyses show that long-term migration of the diversion channel towards the reclaimed impoundment embankment may occur, and therefore a six thick layer of well graded rock, which has a D_{50} of three (3) inches, should be entrenched from the toe of the impoundment to three feet below the diversion channel floor. This material will stabilize the impoundment outslope near the diversion channel from any potential lon-term channel migraation. This material will be extended one (1) foot above the channel floor also. The same 6-hour, 25-year storm event was utilized for these analyses. Appendix F contains calculations for runoff quantities and erosion protection material sizing for the diversion channel.

4.5 Modified Alternative Construction Sequencing

Hecla's Modified Alternative consists of substituting a CCL (Blue Clay) for the GCL Barrier Layer. Other than that one substitution, all other construction sequencing would remain the same as for the Selected Alternative. However, due to potential difficulties with obtaining sufficient quantities of Blue Clay in a timely manner, the overall construction process utilizing a CCL may be longer. In addition, water needs would most likely be greater, and more time would be required for processing, compacting, and quality assurance testing of the CCL.

5.0 COST ESTIMATE

The estimated total cost range for construction of the Selected Alternative (GCL) for the final cover system is $343,920 to $400,692. The estimated total cost range for construction of the Modified Alternative (Blue Clay) is $290,920 to $366,392. Major cost components for the Selected Alternative are included in Table 4. Appendix G contains a more complete cost estimate that provides details for major cost items, quantities, unit prices, and other factors that were included in the estimate. Theses estimates are based on the assumption that all work will be conducted by contractors and includes their overhead and profit. Unit prices for major earthwork activities and materials were based on cost estimates provided by local and national vendors, local material prices, and local equipment rates.

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Table 1
Configuration of Typical Cover Systems

Layer	Primary Functions	Construction Materials	General Considerations for Apex Site / Pond 2
(1) Surface	➢ promotes vegetative growth ➢ decreases erosion ➢ protects underlying layers from intrusion ➢ promotes evapotranspiration	topsoil or gravel / cobbles	required to minimize wind / water erosion
(2) Protection	➢ protects underlying layers from dessication, freeze-thaw, and intrusion ➢ maintains stability and storage of water	mixed soils or gravel / cobbles	required for protection of Barrier Layer (freeze-thaw and dessication)
(3) Drainage	➢ drains away infiltrating water to dissipate seepage forces	sands, gravels, geotextiles, geonets, or geocomposites	not necessary due to arid climate (low precipitation / high evaporation rate)
(4) Barrier	➢ minimizes infiltration of surface water ➢ reduces gas emissions	compacted, GCL (geosynthetic clay liner), geomembranes, or composites	although likely needed, does not have to be as low a permeability as 1 x 10^{-7} cm/sec (for RCRA hazardous waste)
(5) Gas Collection	➢ transmits gas to collection points for removal	sand, geotextiles, or geonet	not necessary due to non-gassing producing nature of waste

Table 2
Advantages and Disadvantages of Barrier Layer Materials

Barrier Layer Material	Advantages	Disadvantages
GCL	➢ rapid installation ➢ very low hydraulic conductivity if properly installed ➢ low cost ➢ excellent resistance to freeze-thaw ➢ can withstand large differential settlement ➢ excellent self-healing characteristics ➢ not dependent on locally available soils ➢ low weight and volume consumed by liner ➢ easy to repair	➢ low shear strength of hydrated bentonite ➢ can be punctured during or after construction ➢ dry bentonite is not impermeable to gas ➢ potential strength concerns at interfaces with other materials
CCL	➢ long history of use ➢ regulatory approval is virtually assured ➢ large thickness ensures that layer will not be breached ➢ large thickness provides physical separation between waste and surface environment ➢ cost can be low if material is locally available	➢ soil can dessicate and crack ➢ liner must be protected from freezing ➢ low resistance to cracking from differential settlement ➢ difficult to compact soils above compressible waste ➢ suitable soils not always locally available ➢ difficult to repair is damaged ➢ slow construction
Geomembrane	➢ rapid installation ➢ virtually impermeable to water if properly installed ➢ low cost ➢ not vulnerable to desiccation of freeze-thaw damage ➢ can withstand large tensile strains ➢ low weight and volume consumed by liner ➢ easy to repair	➢ potential strength concerns at interfaces with other materials ➢ can be punctured during or after construction

Table 3
Final Closure Plan Alternatives

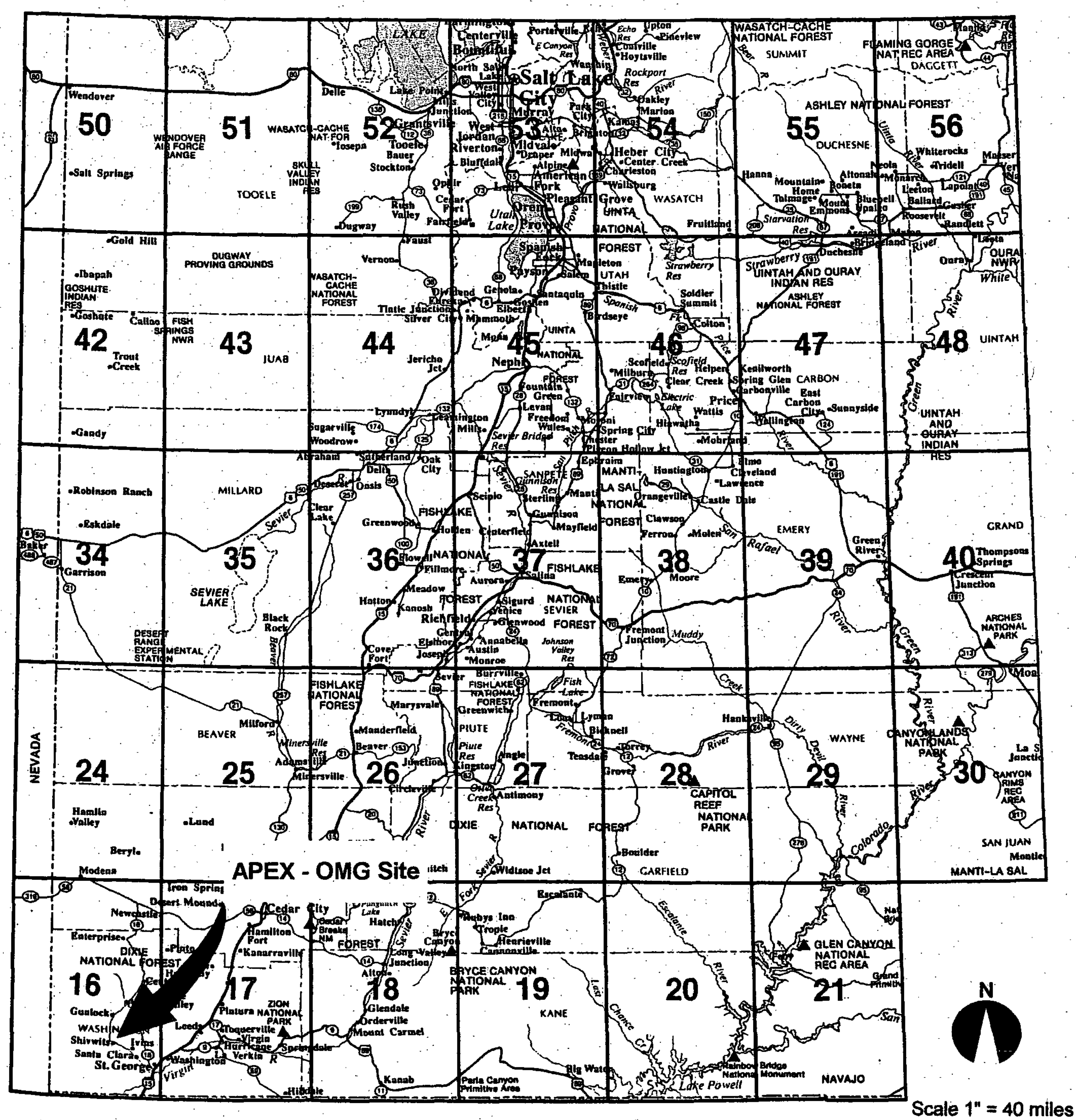
Variables	Alternatives					
	Modified Alternative	Selected Alternative	Rejected Alternatives			
	1 Blue Clay	2 GCL	3 On-Site Materials I	4 VLDPE / HDPE	5 RCRA Type	6 On-Site Materials II
Drainage	Vertical Wicks	Vertical Wicks	Vertical Wicks	Vertical Wicks	Vertical Wicks	No Drains
Top Slope	1%	1%	1%	1%	1%	2%
Cover Layer Descriptions	**Surface Layer** 2" of D_{50} = 1" Rock (outslopes only)	**Surface Layer** 2" of D_{50} = 1" Rock (outslopes only)	**Surface Layer** 2" of D_{50} = 1" Rock (outslopes only)	**Surface Layer** 2" of D_{50} = 1" Rock (outslopes only)	**Surface Layer** 2" of D_{50} = 1" Rock (outslopes only)	
	Protection Layer 12" on-site materials TP-1 (2.6×10^{-6} cm/sec)	**Protection Layer** 12" on-site materials TP-1 (2.6×10^{-6} cm/sec)	**Protection Layer** 12" on-site & off-site materials Shivwits Dam (6.3×10^{-6} cm/sec)	**Protection Layer** 6" on-site materials TP-1 (2.6×10^{-6} cm/sec)	**Protection Layer** 18" on-site & off-site materials	**Protection Layer** 12" on-site & off-site materials Shivwits Dam (6.3×10^{-6} cm/sec)
					Biotic Barrier Layer 6" Cobble	
					Geosynthetic Filter	
					12" Drainage Layer	
					20-mil Geomembrane	
	Barrier Layer 12" thick Blue Clay (approx. 1×10^{-7} to 1×10^{-8} cm/sec)	**Barrier Layer** GCL (1 to 5×10^{-9} cm/sec)	**Barrier Layer** 12" on-site materials TP-1 (2.6×10^{-6} cm/sec)	**Barrier Layer** HDPE or VLDPE textured	**Barrier Layer** 24" Blue Clay (10^{-7} to 10^{-8} cm/sec) or GCL (1 to 5×10^{-9} cm/sec)	**Barrier Layer** 12" on-site materials TP-1 (2.6×10^{-6} cm/sec)
				6" Sand Layer		
	Cut & Fill Existing to 1% Slope	Cut & Fill Existing to 1% Slope	Cut & Fill Existing to 1% Slope	Cut & Fill Existing to 1% Slope	Cut & Fill Existing to 1% Slope	Cut & Fill Existing to 2% Slope
	Waste	Waste	Waste	Waste	Waste	Waste
Notes	1, 2, 3, 4	1, 2, 5	1, 2, 6	1, 2, 7	1, 2, 8, 9	6, 10, 11, 12
Est. Cost[13]	**\$190k to \$310k**	**\$240k to \$400k**	**\$210k to \$340k**	**\$300k to \$480k**	**\$570k to \$930k**	**\$90k to \$150k**

Notes for Conceptual Table 3 - Final Closure Plan Alternatives:

1. Vertical wick drains will substantially decrease consolidation time, decrease the amount of additional consolidation after placement of final cover, and speed up the process of removing the Collection Ditch and Evaporation Ponds.
2. Rock (Surface Layer) is in lieu of growth media / revegetation. Rock will provide for superior long-term erosion protection and there will be no requirements for establishment of vegetation.
3. Blue Clay is the best available low-permeability material source in the St. George area. Laboratory tests show permeability is typically less than 1×10^{-7} cm/sec.
4. Blue Clay would potentially take significantly longer to purchase and deliver as it would have to be delivered in a piece-meal fashion.
5. GCL costs are preliminary and dependent on manufacturer, materials, and contractor (installer) selected.
6. Permeability of Barrier Layer estimated at 2.6×10^{-6} cm/sec.
7. 6" sand layer above waste is utilized to protect the HDPE / VLDPE liner.
8. RCRA Type - Typical multilayered cap for RCRA hazardous waste application.
9. Barrier Layer constructed with either 24" Blue Clay or GCL.
10. No drains installed with this alternative so there would be additional problems and costs associated with:
    - longer time to allow for drainage and consolidation
    - potentially more settlement after completion of the cover
    - disposal of Collection Ditch / Evaporation Ponds and liners
    - either installation of new "lined" berm or tie in into old liner
11. Additional costs would need to be added to this alternative due to longer time period required for pumping of fluids on to the top of the impoundment.
12. Pond materials likely to experience additional consolidation after final cover placement with this alternative. Slope design of 2% on the top surface would allow for greater consolidation while maintaining positive drainage off the impoundment.
13. Estimated Costs - Initial estimates for comparison of alternatives only. Costs include purchase, delivery, and placement of cover materials only. No CM, QA/QC, or design costs included.

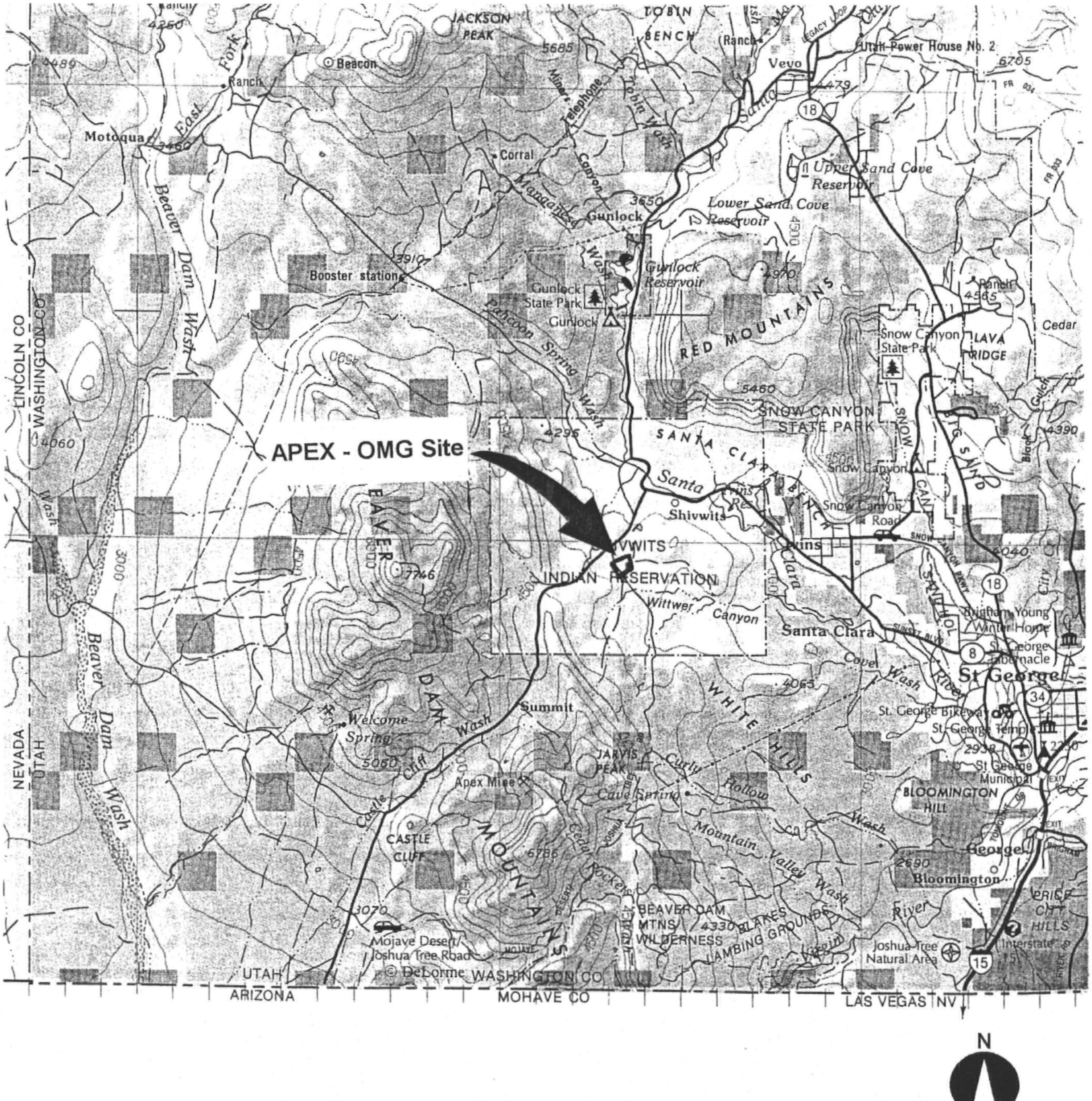
Table 4
Cost Estimate - Selected Alternative (GCL)

Item #	Item	Quantity	Units	Purchase/ Excavation ($/Unit)	Deliver ($/Unit)	Place ($/Unit)	Total ($/Unit)	Estimated Cost Range Low	Estimated Cost Range High
1	Mobilization - Earthmoving Contractor	1	LS	$2,000	NA	NA	$2,000	$2,000	$2,400
	Phase I - Drainge & Consolidation								
2	Construct Exterior Containment Berm	1	LS	NA	$0	$300	$300	$300	$450
3	Fabricate and Install Settlemement Monuments	6	EA	$50	$0	$200	$250	$1,500	$1,800
4	Install Vertical Wick Drains @ 4 O.C.	200,000	LF	$0.43	$0.075	$0.00	$0.51	$101,000	$111,100
5	Construct Interior Containment Berms @ 30' O.C.	1	LS	NA	$0	$1,280	$1,280	$1,280	$1,664
6	Remove & Dispose Evaporated Salts (top surface)	1	LS	NA	$0	$1,200	$1,200	$1,200	$2,400
7	Remove & Dispose Evap Pond/Coll. Ditch Materials	1	LS	NA	$0	$1,500	$1,500	$1,500	$2,250
	Phase II - Regrading								
8	Excavate Existing Embankment	9,300	CY	NA	$0	$0.56	$0.56	$5,250	$7,875
9	Place Preloading on Top Surface	9,300	CY	NA	$0	$0.32	$0.32	$3,000	$3,600
10	Final Grading of 1% Surface	9,300	CY	NA	$0	$0.24	$0.24	$2,250	$3,150
	Phase III - Final Cover System Construction								
11	Mobilization - GCL Contractor / Installer	1	LS	$2,500	$0.00	$0.00	$2,500	$2,500	$3,000
12	Place Barrier Layer (GCL) - top	195,750	SF	$0.25	$0.05	$0.10	$0.40	$78,000	$85,800
13	Place Barrier Layer (GCL) - outslopes	49,500	SF	$0.31	$0.05	$0.10	$0.46	$23,000	$25,300
14	Strip & Grub Vegetation	1	LS	$0.00	$0.00	$2,250	$2,250	$2,250	$2,700
15	Excavate Diversion Channel	11,500	CY	$0.65	$0.26	$0.00	$0.91	$10,500	$12,600
16	Place Protection Layer (12" on-site materials)	8,000	CY	$0.00	$0.25	$0.56	$0.81	$6,500	$10,400
17	Reconstruct Outside Embankment	3,500	CY	$0.00	$0.29	$1.81	$2.10	$7,350	$11,025
18	Finish Grade 1% Surface - top	1	LS	$0.00	$0.00	$2,250	$2,250	$2,250	$4,500
19	Place Surface Layer (outslopes only) D50 = 1"	300	CY	$7.00	$4.00	$5.00	$16.00	$4,800	$5,760
20	Place Diversion Channel Erosion Protection (3" rock)	200	CY	$7.00	$4.20	$7.75	$18.95	$3,790	$4,548
21	Dust / Erosion Control	1	LS	$2,700	NA	NA	$2,700	$2,700	$2,970
22	QA / QC	60	Days	$650	NA	NA	$650	$39,000	$46,800
23	Construction Management	60	Days	$500	NA	NA	$500	$30,000	$33,000
24	Surveying (Settl. Mon., All Surfaces)	15	Days	$800	NA	NA	$800	$12,000	$18,000
							Totals	$343,920	$400,692



PROJECT Apex LOCATION St. George, Utah DATE 8/17/03	**Figure 1** **Site Location Map**

This drawing is the property of HECLA MINING COMPANY. This drawing is furnished for the sole use of the recipient and acceptance of same constitutes an agreement that it will not be published, reproduced, or given to any other party without our permission unless furnished to recipient under contract provisions and shall remain the property of Hecla Mining Company subject to return on request.	Prepared by: Monster Engineering Inc.	Prepared for: Hecla MINING COMPANY

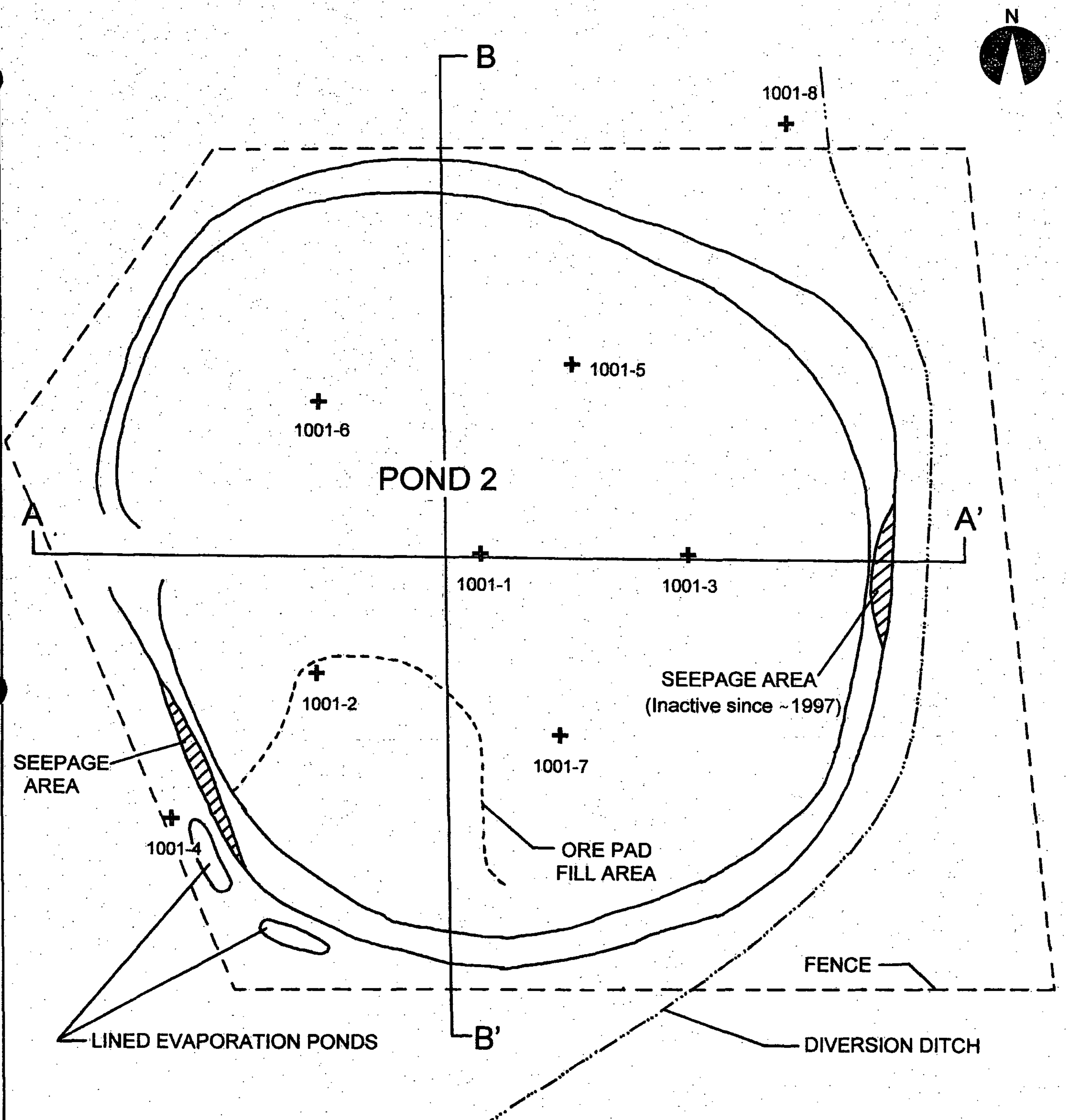


PROJECT Apex
LOCATION St. George, Utah
DATE 8/17/03

Figure 2
Project Location Map

Prepared by:
Monster Engineering Inc.

Prepared for:
Hecla MINING COMPANY



Scale 1" = 100'

Note: + 1001-8 = Bore Hole Locations

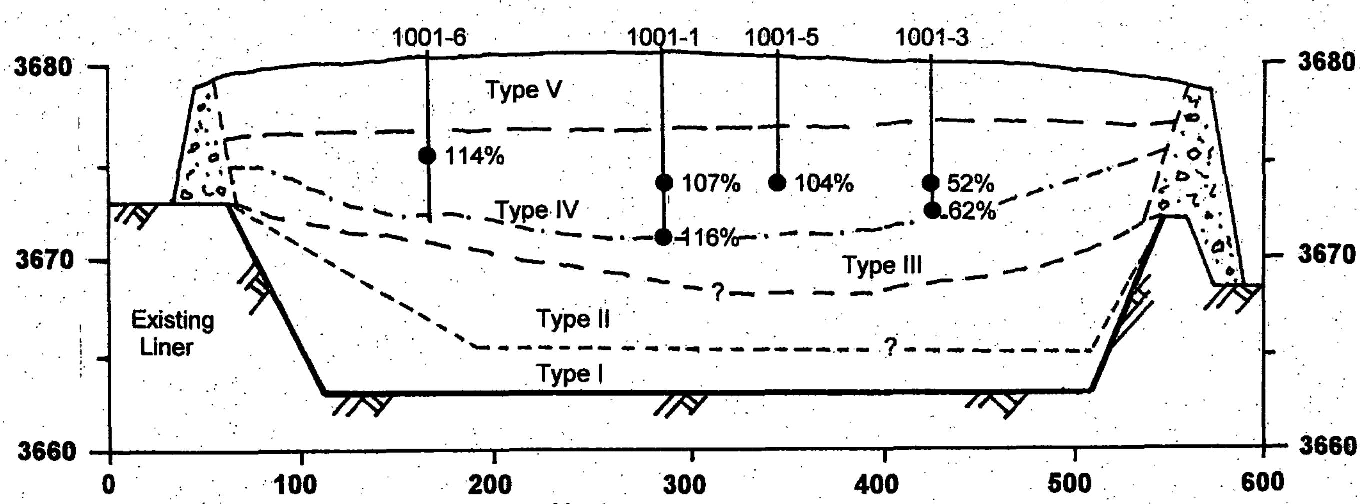
PROJECT **Apex**
LOCATION **St. George, Utah**
DATE **8/17/03**

Figure 3
Pond 2 - Plan View

Prepared by:
Monster Engineering Inc.

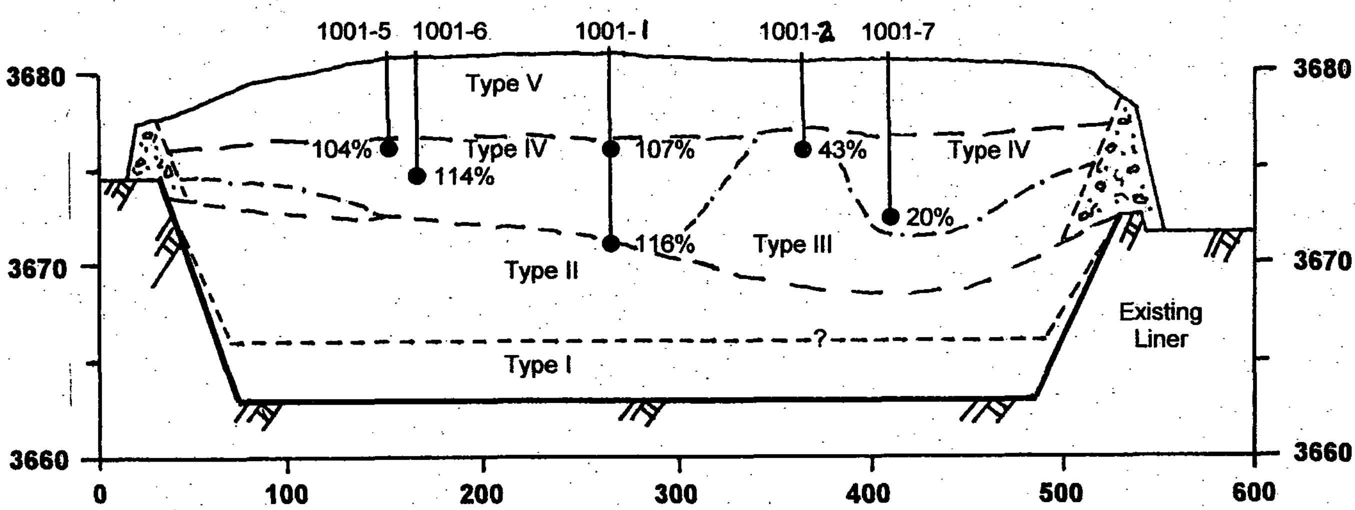
Prepared for:
Hecla MINING COMPANY

Section A - A'



Horizontal: 1" = 100'
Vertical: 1" = 10'

Section B - B'



Material Types:
I - SGMC Tailings
II - SGMC 2A, 1B, 1C, 3BN, 3BS, 3A
III - Hecla Pond 1A/B - Soil Mixture
IV - Hecla Pond 3A (plus old liner materials, pumped as slurry)
V - Temporary Cover Material

Notes:
• 114% (sample moisture content)
Pond Contents are estimates only.
Borehole locations are estimates.

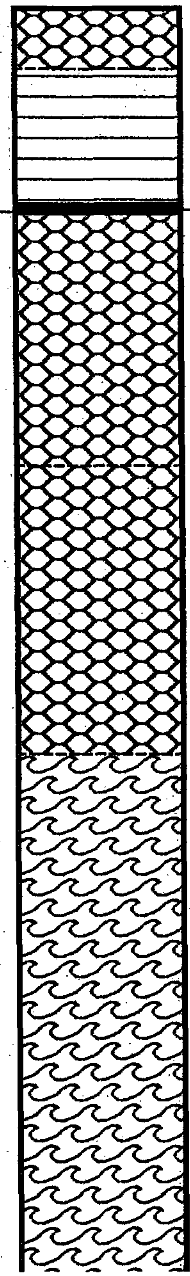
PROJECT Apex
LOCATION St. George, Utah
DATE 8/17/03

Figure 4
Pond 2 - Profiles

Prepared by:
Monster Engineering Inc.

Prepared for:
Hecla MINING COMPANY

Selected Cover System Alternative Profile



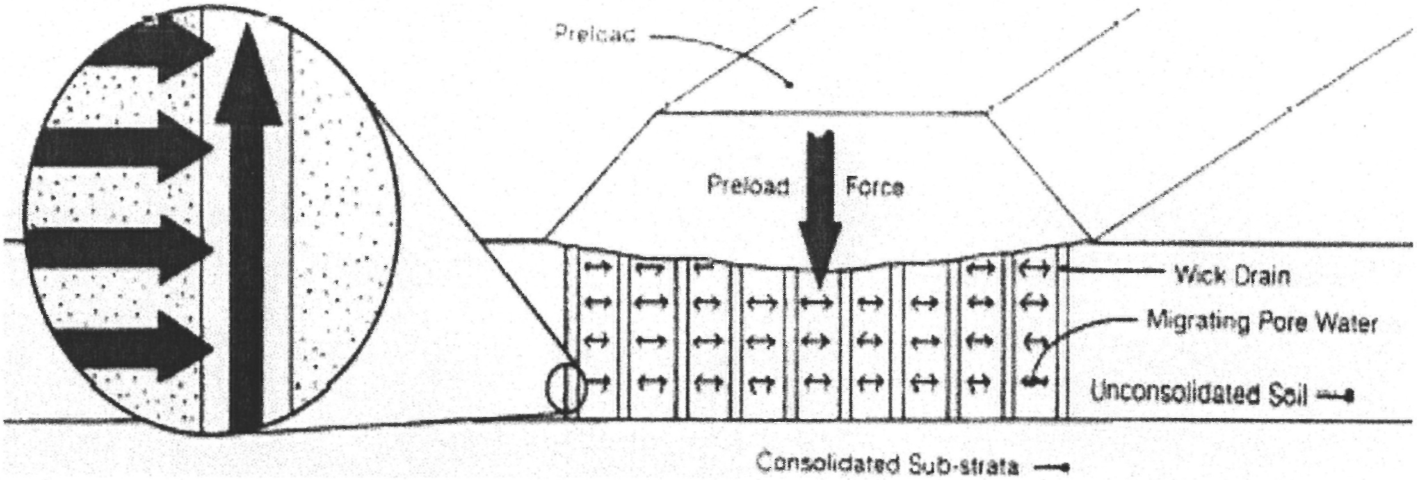
Name	Material
Surface Layer	2" of D_{50} = 1" well graded rock (outslopes only)
Protection Layer	12" of sandy clay with gravel, on-site material designated as TP-1, typical permeability of approximately 2.6×10^{-6} cm/sec
Barrier Layer	GCL (geosynthetic clay liner) typical permeability of 5×10^{-9} cm/sec
Regraded Existing Cover and Embankment Materials	0" to 24" of sand to cobbles mixed with some topsoil, cut and fill to 1% slope
Temporary Cover	24" to 54" of sand to cobbles mixed w/ some topsoil
Waste Materials	12' to 14' of various waste materials

PROJECT Apex
LOCATION St. George, Utah
DATE 8/17/03

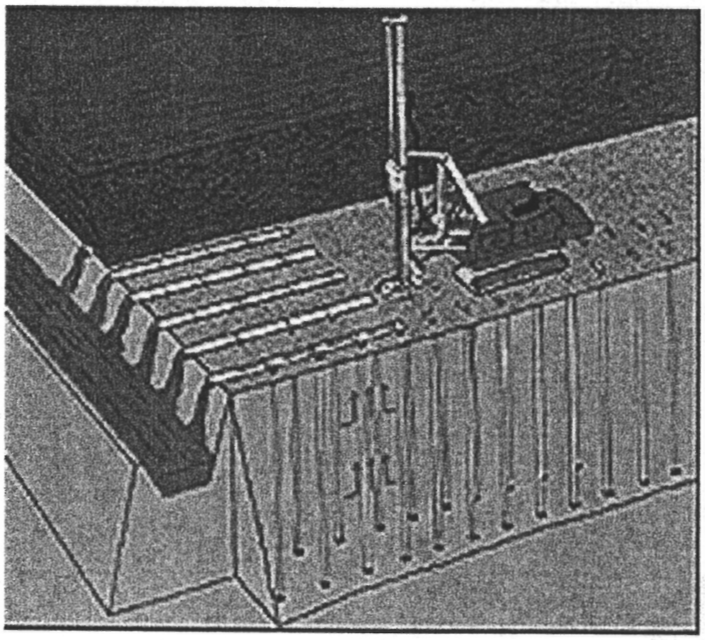
Figure 5
Selected Cover System Alternative Profile

Prepared by: Monster Engineering Inc.

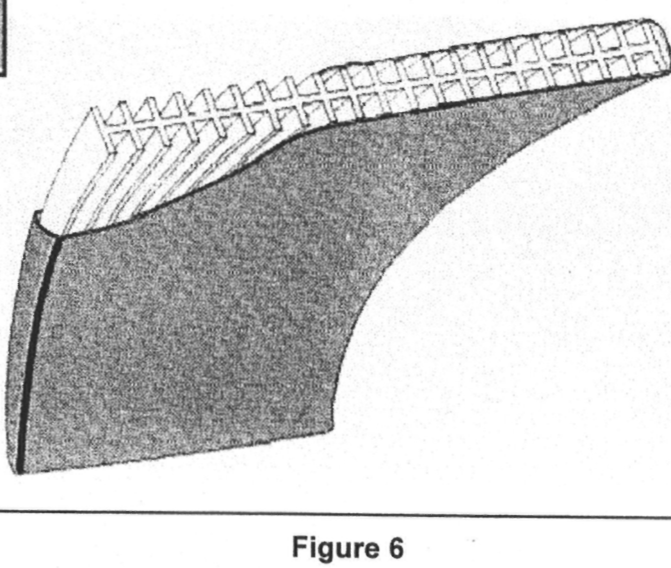
Prepared for: Hecla Mining Company



Consolidating Using Wick Drains



Typical Installation - 3.4' to 5.4' horizontal spacing



Cutaway Section of Mebra Wick Drain
(from NILEX)

PROJECT **Apex**
LOCATION **St. George, Utah**
DATE **8/17/03**

Figure 6

Typical Vertical Wick Drain Installation

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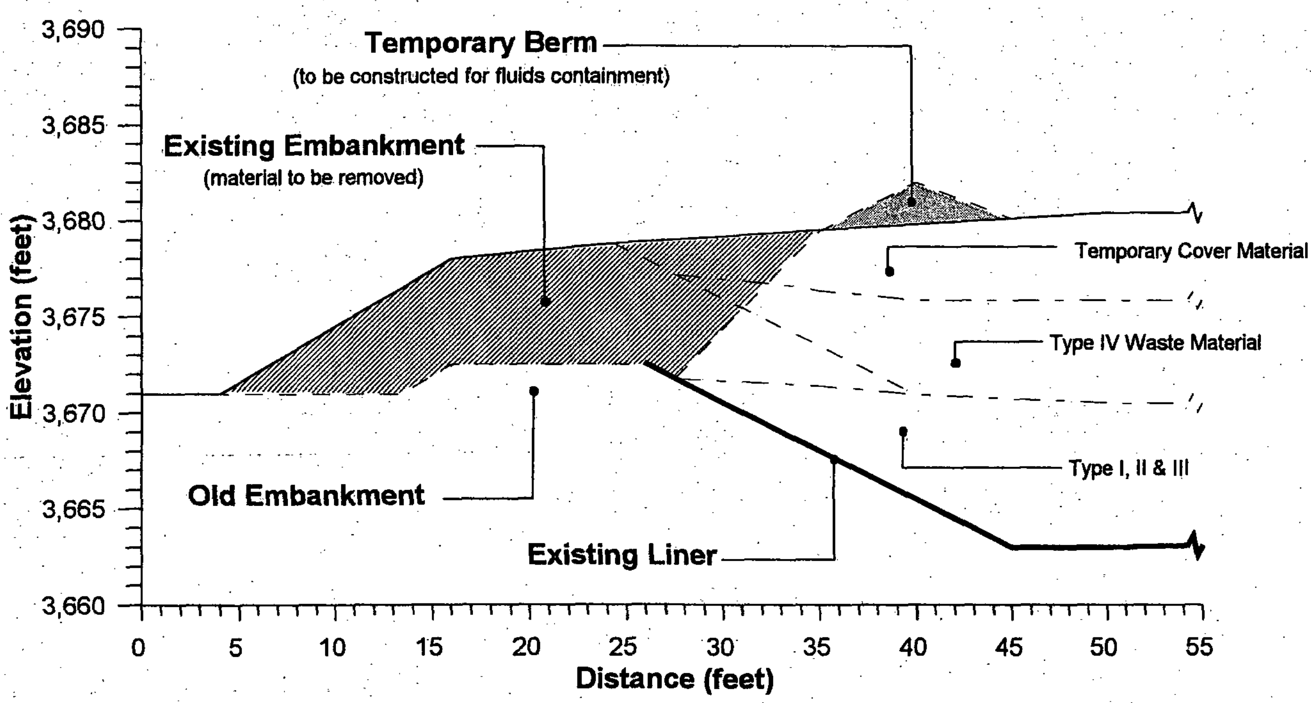
Monster Engineering Inc.

Prepared for:

Hecla MINING COMPANY

Typical Embankment Profile

(pre-embankment removal)



1" = 10' H = V

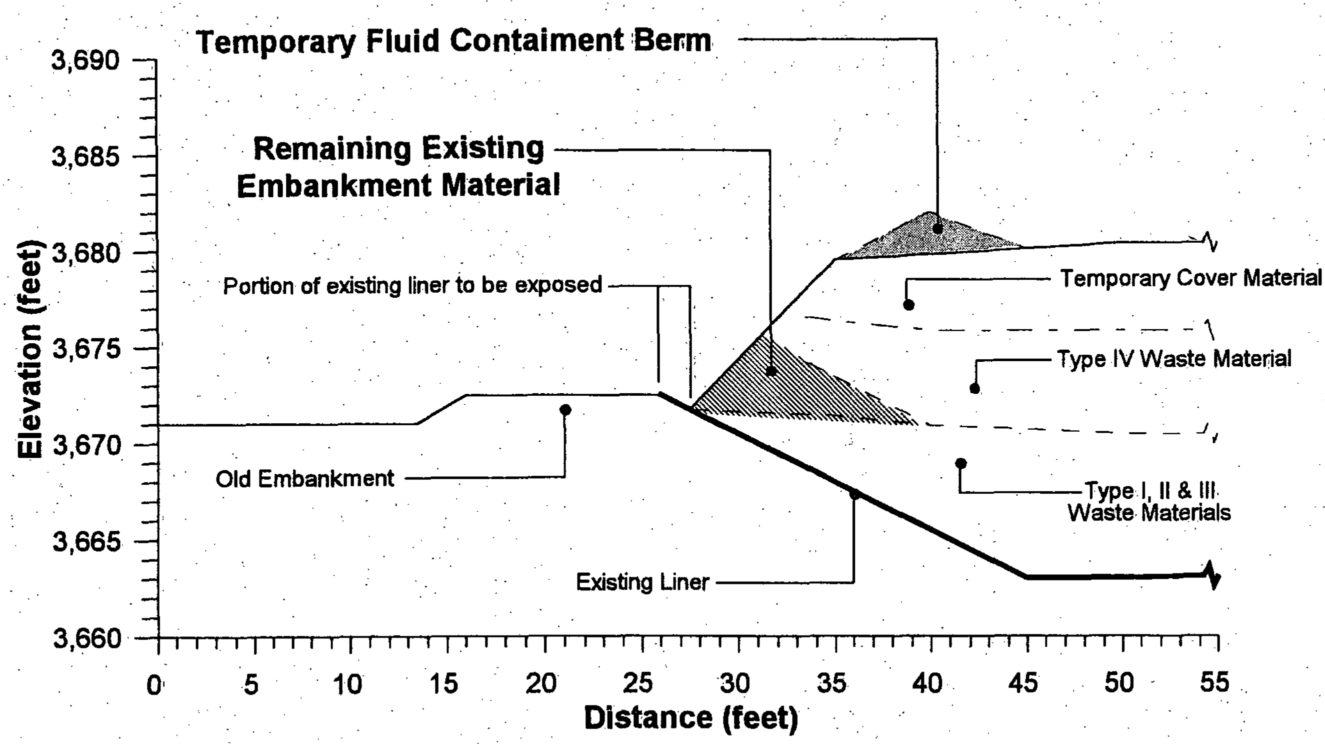
PROJECT Apex LOCATION St. George, Utah DATE 8/17/03	**Figure 7** **Typical Embankment Profile** **(pre-embankment removal)**

Prepared by: *Monster Engineering Inc.*

Prepared for: Hecla Mining Company

Typical Embankment Profile

(post-embankment removal)



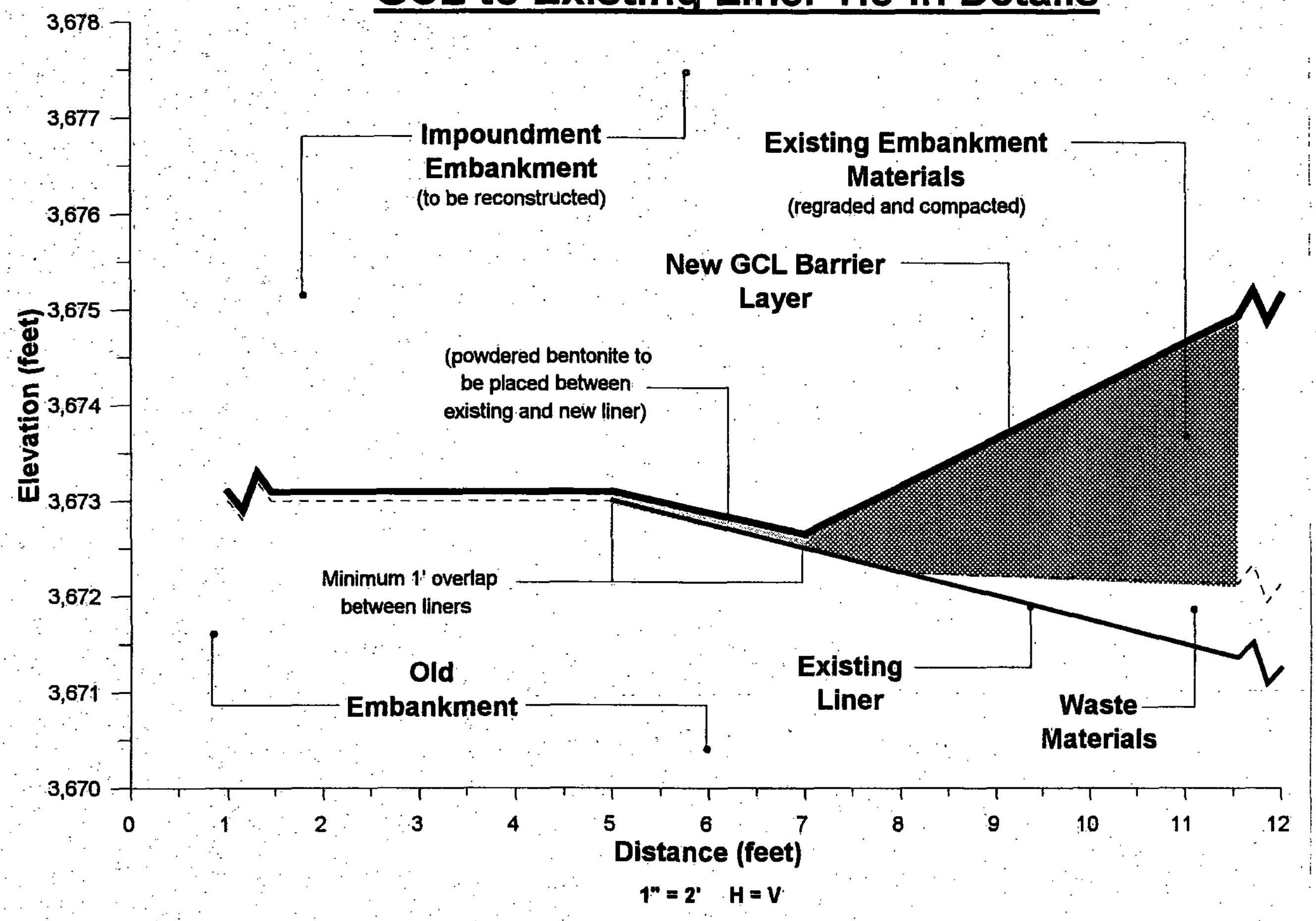
1" = 10' H = V

PROJECT Apex LOCATION St. George, Utah DATE 8/17/03	**Figure 8** **Typical Embankment Profile** **(post-embankment removal)**

Prepared by: Monster Engineering Inc.

Prepared for: Hecla Mining Company

GCL to Existing Liner Tie-in Details



PROJECT Apex
LOCATION St. George, Utah
DATE 8/17/03

Figure 9

GCL to Existing Liner Tie-in Details

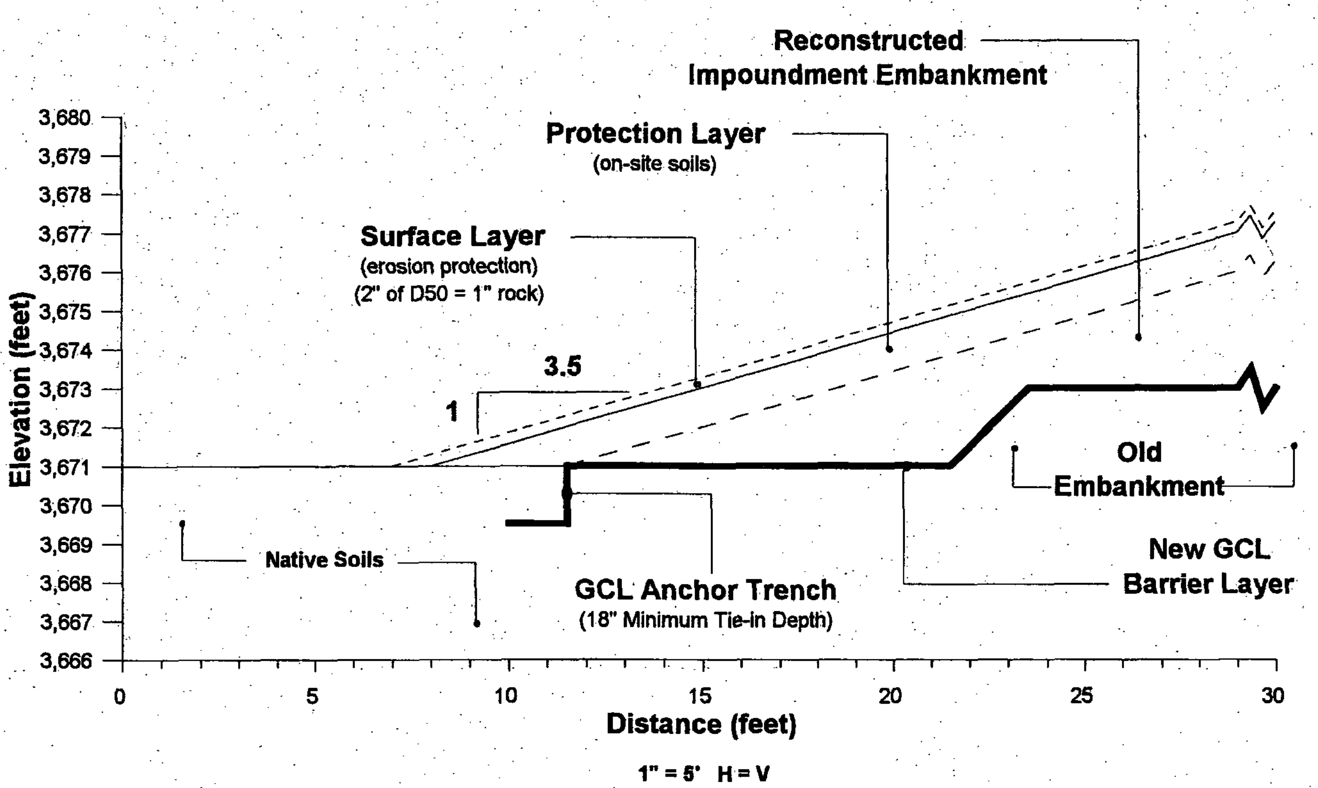
Prepared by:

Monster Engineering Inc.

Prepared for:

Hecla MINING COMPANY

GCL to Native Soils Tie-in Details



PROJECT	Apex
LOCATION	St. George, Utah
DATE	8/17/03

Figure 10

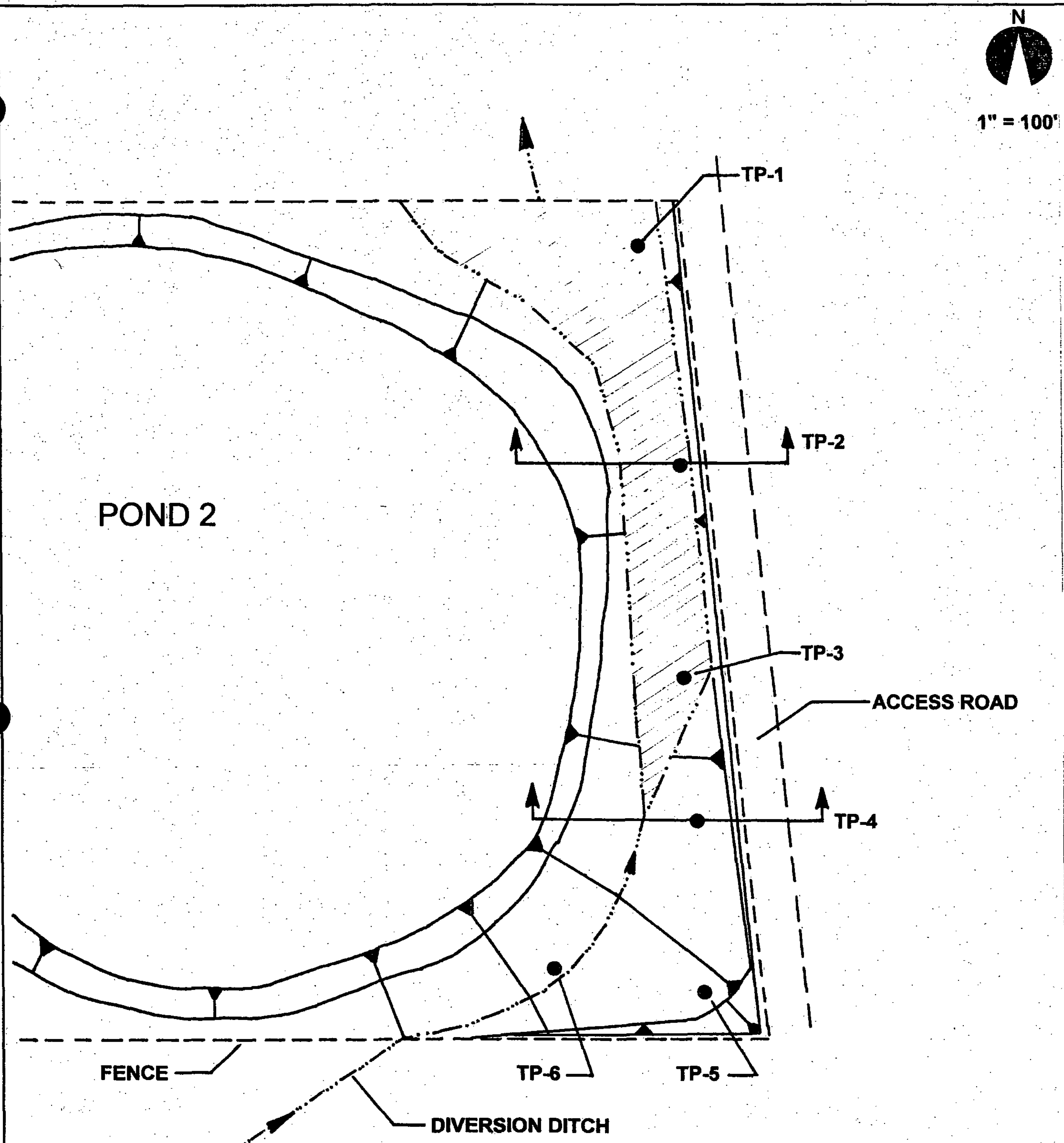
GCL to Native Soils Tie-in Details

Prepared by:

Monster Engineering Inc.

Prepared for:

Hecla MINING COMPANY



Note: TP-1 = Test Pit Number 1

PROJECT Apex
LOCATION St. George, Utah
DATE 8/17/03

Figure 11

Borrow Area / Diversion Channel Plan View

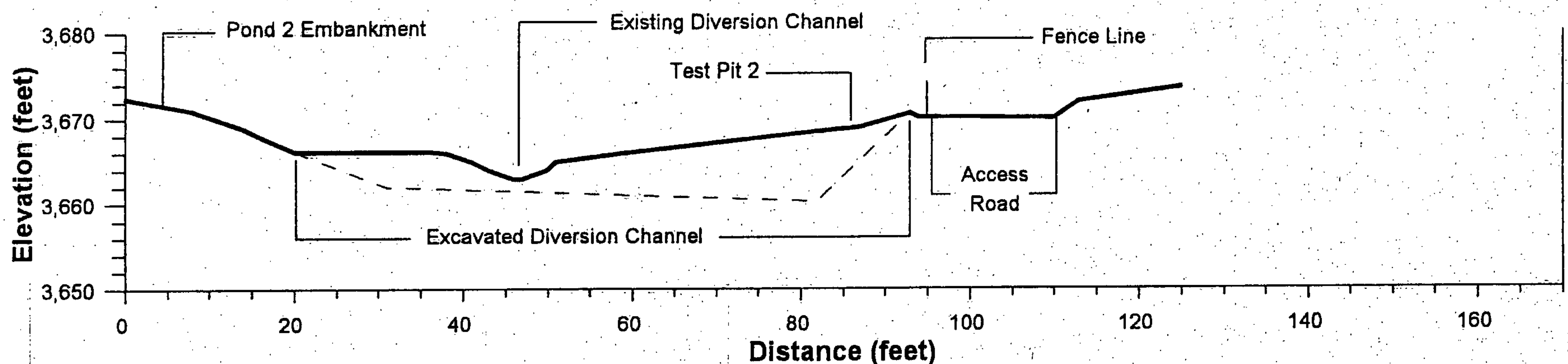
Prepared by:

Monster Engineering Inc.

Prepared for:

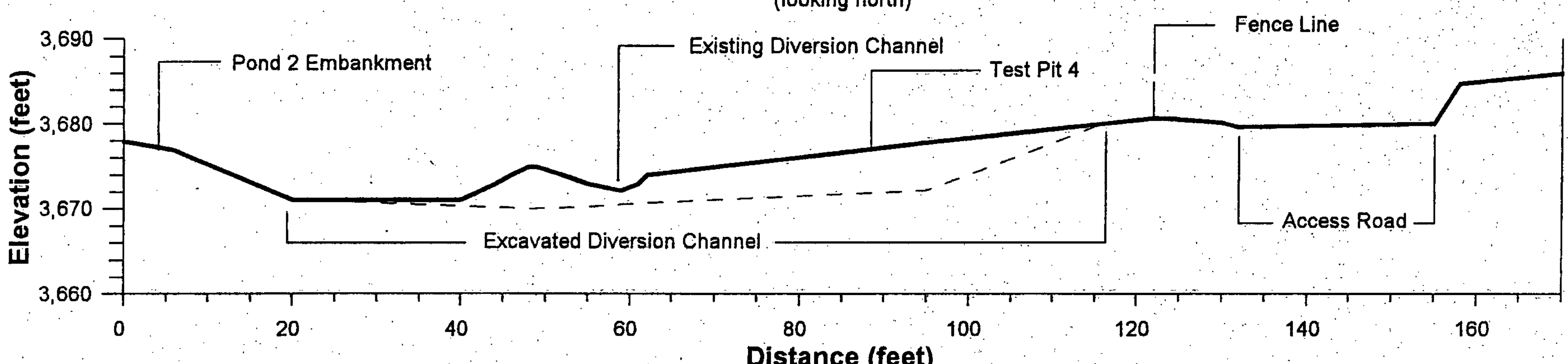
Hecla MINING COMPANY

Channel Cross Section at TP- 2
(looking north)



1" = 20' Horizontal = Vertical

Channel Cross Section at TP- 4
(looking north)



1" = 20' Horizontal = Vertical

PROJECT **Apex**
LOCATION **St. George, Utah**
DATE **8/17/03**

Figure 12

Borrow Area / Diversion Channel Excavation Profiles

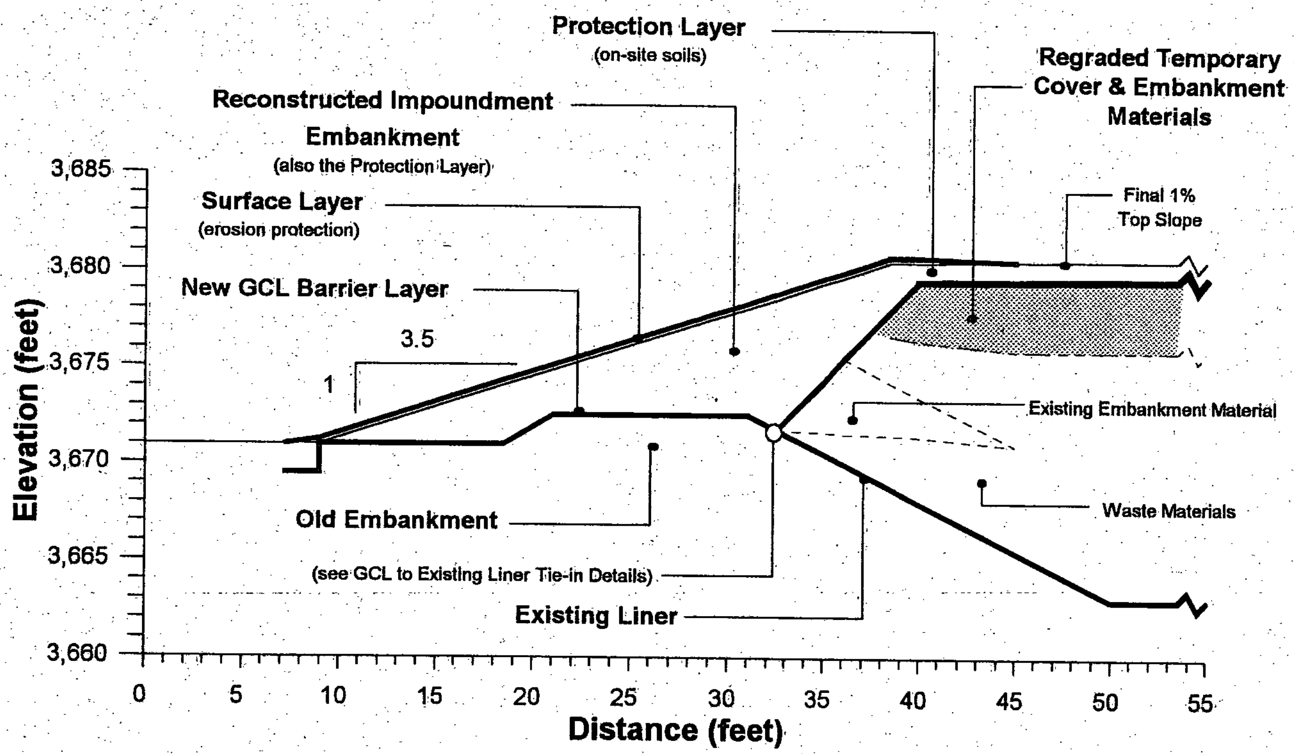
Prepared by:

Monster Engineering Inc.

Prepared for:

Hecla Mining Company

Reconstructed Embankment Profile



1" = 10' H = V

PROJECT Apex
LOCATION St. George, Utah
DATE 8/17/03

Figure 13

Reconstructed Embankment Profile

Prepared by:

Monster Engineering Inc.

Prepared for:

Hecla Mining Company

Apex Site

Engineering Report
for
Pond 2 Final Closure

Appendices

Appendix A & B Waste / Borrow	Appendix C HELP Results	Appendix D Wick Drains	Appendix E Stability	Appendix F Runoff	Appendix G Cost Estimate	Appendix H M & M Plan	Appendix I CQC Plan

Appendix A

Waste Material Sampling and Analysis - Laboratory Testing Results Summary

Appendix A
Waste Material Sampling and Analysis - Laboratory Testing Results Summary

In October of 2001 Hecla conducted a drilling, sampling, and laboratory testing program to determine the extent of, and potential for, seepage migration from Pond 2 (the impoundment) at Hecla's Apex Site near St. George, Utah. Eight relatively undisturbed samples of Type IV waste materials were successfully collected from various depths within the impoundment. Type IV wastes were the last layer of waste materials placed prior to construction of the temporary cover. Sample test results are summarized in Table 1 below.

Table 1
Material Type IV - Laboratory Test Results Summary

Borehole Number	Sample Depth (ft)	Moisture Content (%)	Liquid Limit	Plastic Limit	Specific Gravity	Permeability (cm/sec)	Percent Passing #200 Sieve
1001-1	5 - 7	107	83	31	3.58	3.7×10^{-6}	99.3
1001-1	8.5 - 9	116	76	21	3.73	NT	93.6
1001-2	5.5	43	NA	NP	3.35	NT	46.7
1001-3	5.5 - 6	52	54	10	3.03	NT	66.1
1001-3	6.5 - 7	62	54	9	3.38	NT	72.5
1001-5	6 - 6.5	104	82	30	3.39	NT	98.5
1001-6	6.5 - 7	114	84	34	3.33	NT	96.3
1001-7	8 - 9	20	27	8	3.11	NT	36.1

NT - not tested

Moisture contents of this waste type ranged from 20% to 116%, and in general increased with depth and distance away from seepage areas located at the outer embankment of the impoundment. Laboratory test results show that Type IV waste is also generally very fine grained as between 36 and 99 percent of the materials are smaller than the #200 sieve. Laboratory permeability of the one remolded sample (borehole 1001-1, 5 to 7 feet) was 3.7×10^{-6} cm/sec, indicating that seepage rates through Type IV materials have been and will continue to be very slow.

Due to the desire to not damage the bottom liner, and some uncertainty in the actual elevation of that liner, Material Types I through III (below Type IV waste materials) were most likely not sampled during the investigation. Although moisture contents of material Types I through III are currently unknown, it is known that Material Type I included tailings and Material Type II included materials pumped into the impoundment as slurry. Moisture contents of these materials may therefore be relatively high, although they have been and continue to be under much greater consolidation pressure than Material Type IV.

Appendix B

Potential Borrow Source Materials Investigation

Appendix B - Potential Borrow Source Materials Investigation

Summary

Monster Engineering Inc. (MEI) conducted a borrow source materials investigation at Hecla's Apex Site, on surrounding OMG and Shivwits properties, and at other nearby potential material sources from November 13th through 15th, 2002. Table 1 below summarizes material classifications, available quantities, and other information collected at the various potential borrow material sites. Four potentially low-permeability materials and several other potentially acceptable borrow materials were identified for use in the Final Closure Plan for Pond 2.

Table 1
Potential Borrow Materials Summary

Location	Sample Name	Classification	Estimated Available Volume (cy)	Distance to Site (miles)	Estimated Cost Delivered (per cy)	Materials Owner
Apex Site	Hecla TP-1 Caliche	SM - silty **Sand** with gravel	1,700	0	$0	Hecla
Apex Site	Hecla TP-3	CL - sandy lean **Clay**	8,200	0	$0	Hecla
Shivwits Land	Shivwits Dam	CL-ML - sandy, silty **Clay**	11,000	1.5	$2 + $_[1]	Shivwits
St. George	Blue Clay	CL/CH - **Clay**	___[2]	~13	$3[3]	various

1 Purchase cost is currently unknown.
2 Availability is dependent on construction activity in St. George (several thousand cy available during November field investigation).
3 Most clay from the St. George area is given away (no cost for material) as it is expansive and not suitable when beneath foundations.

Several additional potential material sources, other than those listed in Table 1, were investigated, sampled, and tested, however materials from these sources were either too coarse grained (high-permeability), too far from the project site (too expensive to purchase and deliver), or had insufficient quantities available.

Limited information concerning topography, soils, vegetation, and drainage was also collected during the field investigation. This information was used during the design of surface water diversion and erosion control facilities.

Background

The primary objective for the investigation was to identify sources, quantities, ownership, and index properties of potentially suitable borrow materials that could be utilized for final reclamation of Hecla's Pond 2. Potential source owners and others potentially knowledgeable of borrow sources included the BLM, the

Utah Department of Transportation (UDOT), private pit operators, construction/excavation contractors, geotechnical materials testing companies, and trucking contractors. Information collected during this initial phase included low-permeability material availability, estimated material and trucking costs, and distance to the site.

Potentially suitable cover materials were determined to be those which could under the correct moisture and compaction conditions achieve a generally low permeability (1×10^{-6} to 1×10^{-8} cm/sec). A low-permeability material was required to achieve the design intent of minimizing infiltration of surface water through the final cover.

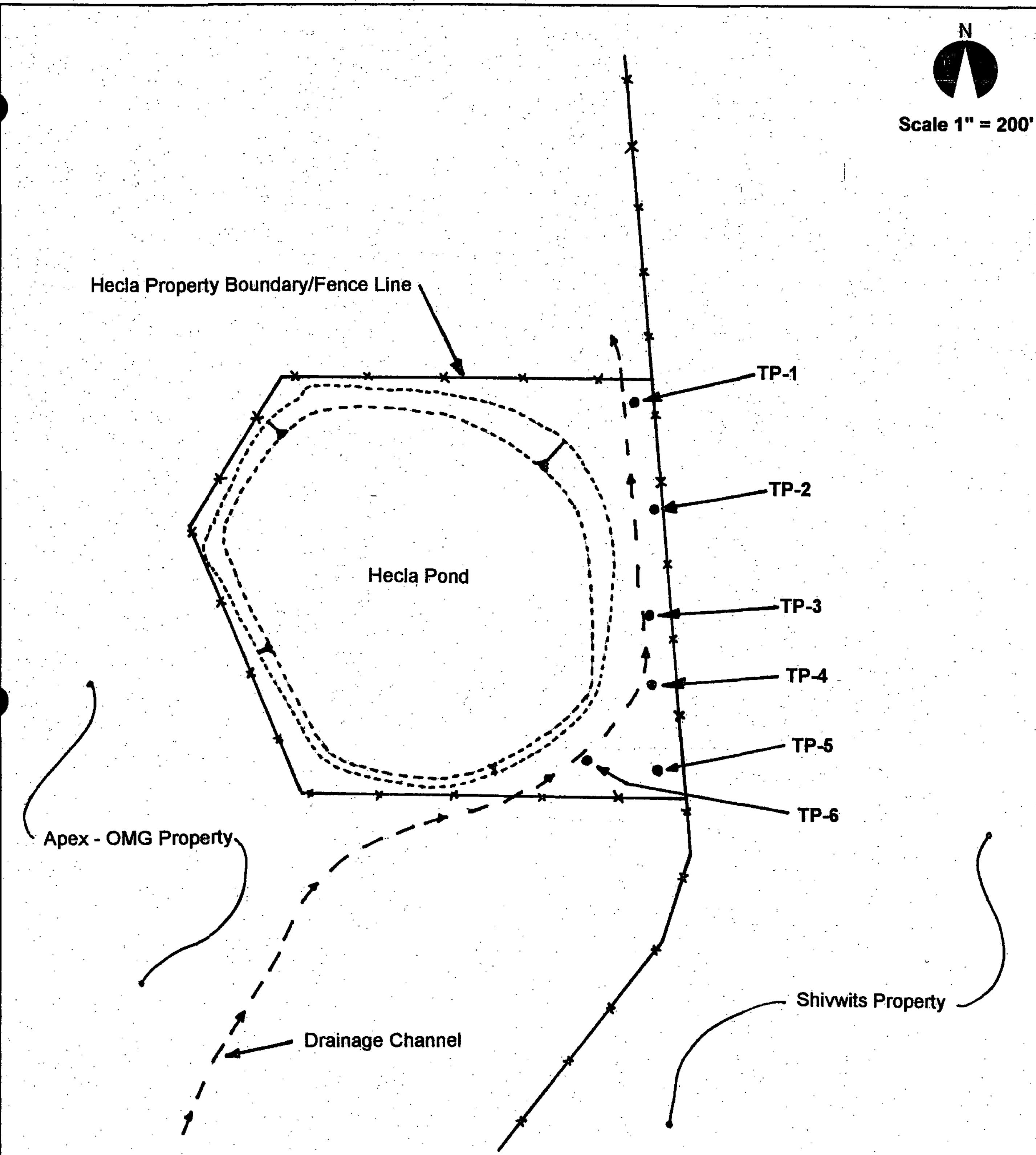
Many different potential source sites were inspected to verify material types and available quantities. Small composite bag samples were collected from each source and examined in order to qualitatively compare materials including grain size distribution (potential for achieving low-permeability). The number of potential source sites was then narrowed by utilizing a criteria of reasonable distance to the Apex Site, and therefore reasonable delivery cost, and low-permeability potential (some contacts were overly optimistic).

Seven potential borrow source sites fit the preceding criteria including five off-site sources and two on-site sources. Two of the five off-site sources were located near Gunlock (approximately 10 miles north of the site), two off-site sources were located in and near St. George (between 11 and 13 miles to the site), and the last off-site source was located on Shivwits land about 1.5 miles from the Apex Site. The on-site materials source was located immediately adjacent to and east of Pond 2 on Hecla property. These seven sources were given the following names:

- Gunlock Desert Sage
- Gunlock L & M Clay
- Progressive Number 2
- Blue Clay
- Shivwits Dam
- Hecla TP-1
- Hecla TP-3 Caliche

Off-Site Sources

The potentially most suitable off-site sources were revisited and representative composite samples were collected (5-gallon bucket size) from individual stockpiles for laboratory testing. The only source from which a sample was not collected was the Blue Clay, as the particular material stockpile available for sampling had been excavated from a future home site and was in the process of being shipped off-site for "disposal". According to local soils engineers and a geotechnical testing company, Blue Clay is removed from many different sites in the St. George area. It is expansive (very low permeability) and must be over-excavated when located directly beneath foundations. It is either disposed of, or used in specific projects which require low-permeability materials such as lining ponds or covering disposal areas (landfills).



PROJECT Apex
LOCATION St. George, Utah
DATE 8/17/03

Figure 1

Pond 2 and Test Pit Locations

Prepared by:

Monster Engineering Inc.

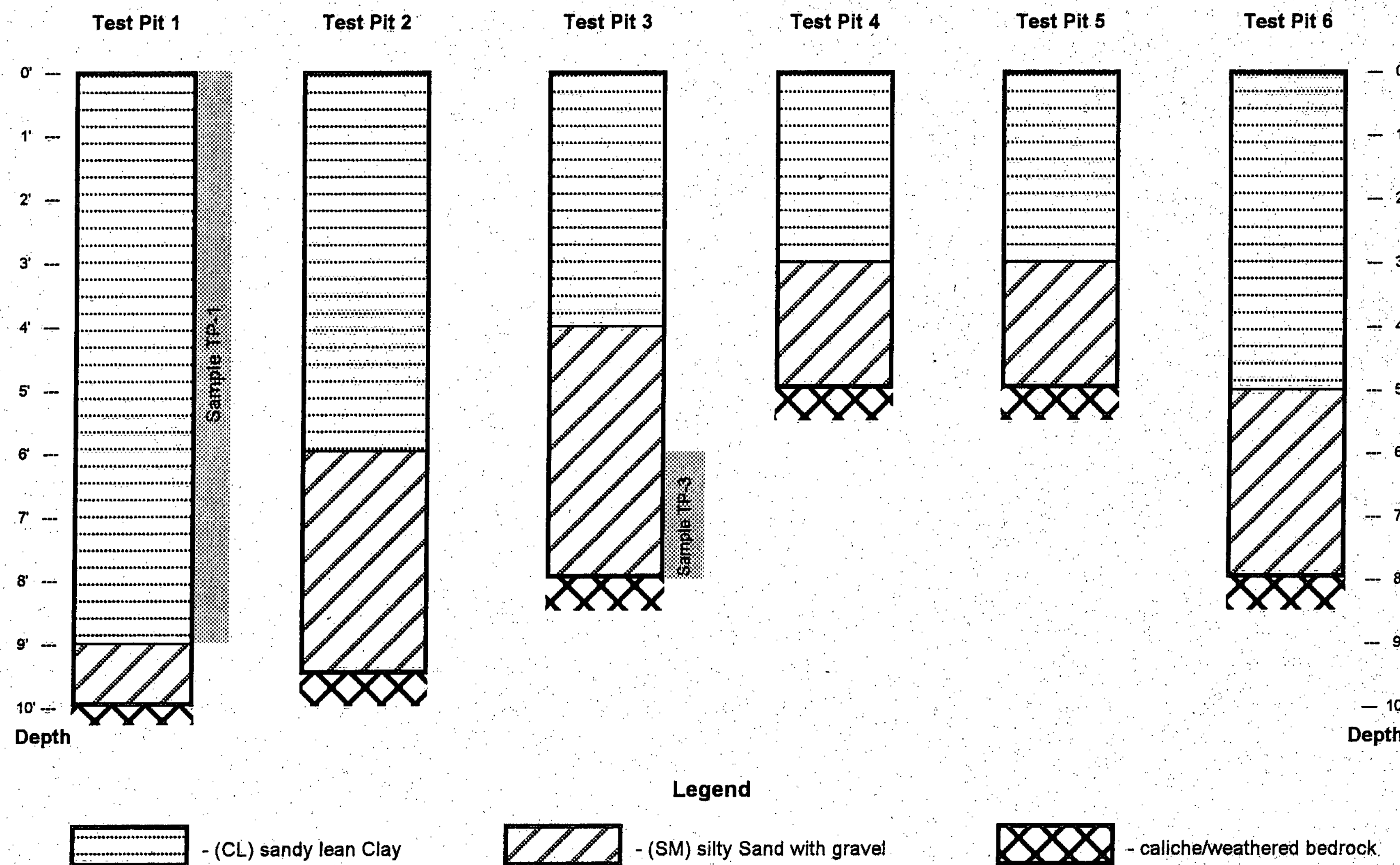
Prepared for:

Hecla Mining Company

On-Site Sources

Six test pits were excavated at the Apex Site on Hecla's property immediately east of and adjacent to the impoundment to determine the suitability of the on-site materials. These materials were divided into two separate and distinct layers. Composite 5-gallon bucket samples were collected from each layer for index testing. The first material layer, represented by sample TP-1, was a sandy lean clay that ranged in thickness from 3 to 9 feet, and the second material layer, represented by sample TP-3 Caliche, was a silty sand with gravel that ranged in thickness from 1 to 4 feet. Test pit locations are shown on Figure 1 on the following page, and test pit logs and composite sample locations are shown on the second page following.

Apex Site - Borrow Source Materials Investigation - Test Pit logs



PROJECT APEX Site
CLIENT Hecla Mining Company
LOCATION St. George, Utah
DATE 8/13/03

MONSTER ENGINEERING INC
ENGINEERING • DESIGN • MANAGEMENT

Laboratory Testing

All 5-gallon bucket samples were delivered to Applied Geotechnical Engineering Consultants, Inc. (AGEC) in St. George for initial laboratory (index) testing. Testing conducted included:

- natural moisture content
- gradation (including percent passing the #200 sieve)
- Atterberg limits (liquid limit and plasticity index)

Testing results are summarized in Table 2 on the following page. Typical Blue Clay material index properties included in the table were provided by AGEC. Each material's classification is shown on the plasticity chart on the second page following.

Additional laboratory testing (permeability, standard proctors, and optimum moisture content) was completed on three of the seven materials based on index test results. These three materials, Hecla TP-1, Hecla TP-3 Caliche, and Shivwits Dam, had the best potential for utilization as a low-permeability cover in the Final Closure Plan.

Quantities/Estimated Cost Summary

Table 3 on the third page following summarizes test results, available quantities, and estimated costs for each of the seven materials sampled and tested during the field investigation.

Table 2 Apex Site - Borrow Source Materials Investigation - Laboratory Testing Program Summary														
						Gradation Analysis (ASTM D-422)								
Sample Number	Sample Name	Sample Depth	Classification	Natural Moisture Content (%)	Optimum Moisture Content (%)	Percent Gravel	Percent Sand	Percent Passing #200	Liquid Limit	Plasticity Index	Maximum Dry Density (ASTM D-698) (pcf)	Permeability (ASTM D-5084)	Comments
1	Gunlock Desert Sage	Grab	SC-SM	4.9		3	68	29	18	4.2			1, 2
2	Hecla TP-3 Caliche	6' - 8'	SM	6.9	14	19	32	49	33	7.4	115.5	1.3×10^{-5}	3
3	Progressive Number 2	Grab	SC	4.7	8.5	18	41	41	23	8.8	127.5		2
4	Gunlock L & M Clay	Grab	CL	5.8		0	36	64	44	21.3			1, 2
5	Hecla TP-1	0' - 9'	CL	4.2	13.5	5	27	68	28	9.7	114.5	2.6×10^{-6}	4
6	Shivwits Dam	Grab	CL-ML	6.2	12	7	32	61	23	5	118.5	6.3×10^{-6}	2
7	Blue Clay	N.A.	CL/CH	8-10	18-20	0	10	90	45-55	20-30	95-105	$10^{-7}/10^{-8}$	5

SC-SM = clayey, silty, fine SAND SM = silty SAND with gravel SC = clayey SAND with gravel CL = sandy lean CLAY CL-ML = sandy, silty CLAY

1 - Sample not chosen for standard proctor and permeability testing due to better and/or more cost effective materials available.
2 - Grab sample was composite collected from many different locations within the pile/location.
3 - Sample was a composite of materials from 6' to 8', and is representative of "caliche" type materials at depth in all test pits at site.
4 - Sample was a composite of materials from surface to 9', and does not include "caliche" type materials which were encountered at 9'.
5 - Results shown are not from a sample collected/tested during MEI's field investigation, but are from similar materials and were provided by Applied Geotechnical Engineering Consultants, Inc. (St. George).

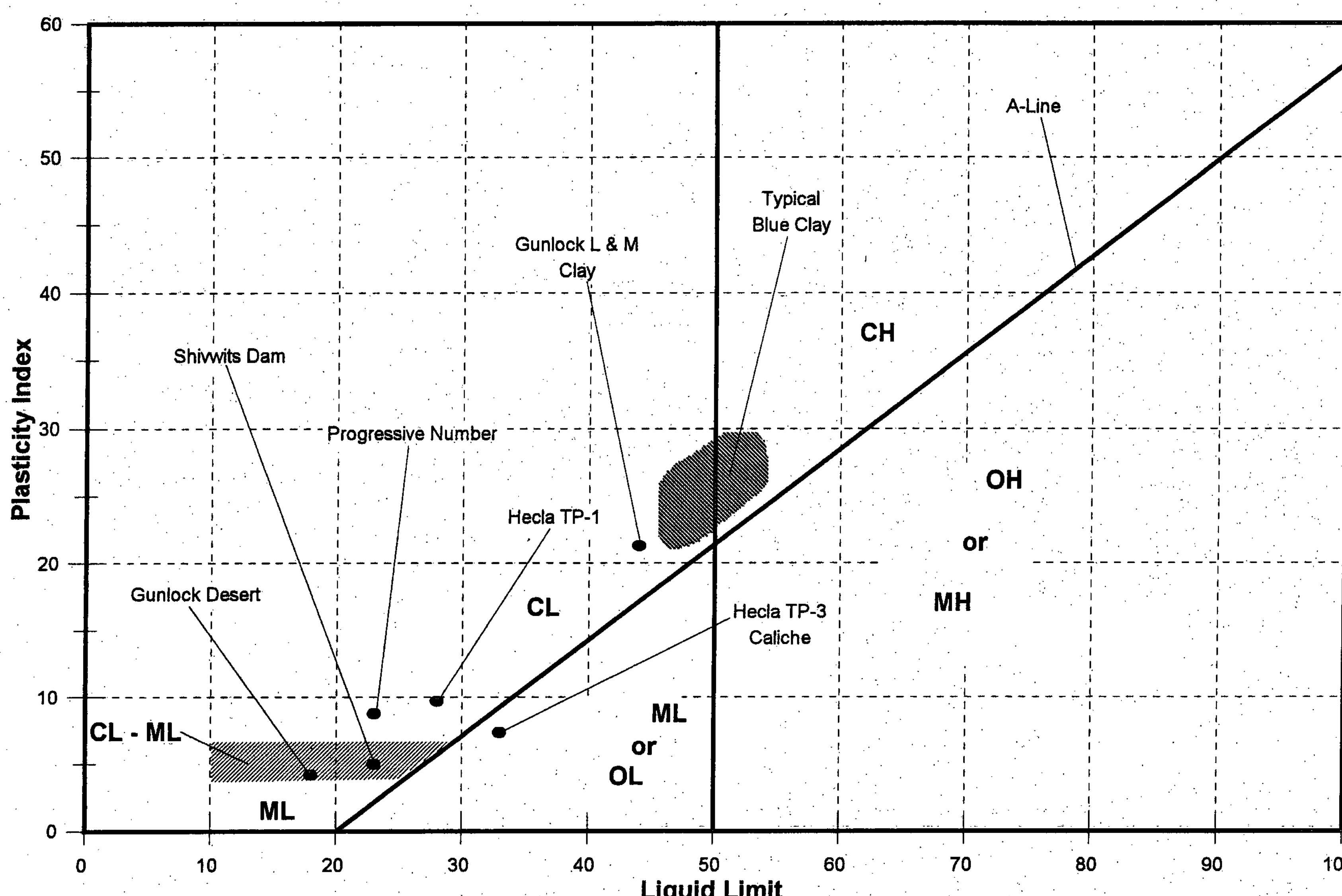
PROJECT APEX Site
CLIENT Hecla Mining Company
LOCATION St. George, Utah
DATE 8/13/03

MONSTER ENGINEERING INC
ENGINEERING • DESIGN • MANAGEMENT

Apex Site - Borrow Source Materials Investigation - Potential Cover Soils

Plasticity Chart

(classification of fine-grained soils)



Monster Engineering Inc.

Table 3
Potential Borrow Materials - Summary

Name	Location	Classification / Name	Estimated Available Volume[1] (cy)	Distance to Site (miles)	Estimated Cost Delivered[2] (per cy)	Materials Owner
Gunlock L & M Clay	Gunlock	CL / sandy lean **Clay**	< 5,000	11.7	$10 to $14	Third party to sell to L & M Construction
Gunlock Desert Sage	Gunlock	SC-SM / clayey, silty fine **Sand**	up to 10,000	10.1	$8	Gunlock Rock
Progressive Number 2	St. George	SC / clayey **Sand** with gravel	>> 10,000	13	$6	Progressive Contracting, Inc.
Blue Clay	St. George (various locations)	CL/CH / **Clay**	__[3]	11- 13	$3[4]	various excavation contractors
Shivwits Dam	Shivwits Land	CL-ML / sandy, silty **Clay**	11,000	1.5	$2 + $__[5]	Shivwits Band
Hecla TP-1	Hecla Property	CL / sandy lean **Clay**	8,200	0	$0	Hecla
Hecla TP-3 Caliche	Hecla Property	SM / silty **Sand** with gravel	1,700	0	$0	Hecla

1 It would take approximately 7,300 cubic yards of material to provide a one foot thick foot cover on Pond 2.
2 Estimated Cost Delivered based on 20 tons/load from Gunlock (singles), 40 tons/load from St. George (doubles), $60/hr trucking costs, 100pcf density, material costs as quoted by each supplier.
3 Quantity available is dependent on construction activity in St. George (several thousand cy were available during the November field investigation).
4 Delivery cost only. Most Blue Clay is given away (no cost for material) as it is expansive and not suitable for beneath foundations.
5 Purchase cost is currently unknown.

Conclusions

Numerous potential borrow materials were examined in order to locate suitable materials for use in the design of the Final Closure Plan for Hecla's Pond 2. Seven potentially acceptable materials (low-permeability) were located, sampled, and submitted for testing. The field of seven potentially acceptable materials was narrowed to four based on field information and laboratory test results.

Rankings of suitability for each of the seven materials tested are shown Table 4 below. Those materials ranked number 5 and lower are most likely not suitable for use as a low-permeability cover. Rankings are qualitative in nature, taking into account available volumes, material cost (purchase and delivery), and potential physical characteristics (permeability).

Table 4
Potential Materials' Suitability Ranking

Ranking	Material	Positives	Negatives
1	Hecla TP-1	• No cost to purchase and ship • Up to 8,200 cy available • Fairly good potential for low permeability (68% passing #200)	• Limited supply
2	Shivwits Dam	• Most likely is OK for low permeability (61% passing #200) • Close to site • Sufficient quantity (11,000 cy)	• Unknown purchase price
3	Hecla TP-3 Caliche	• No cost to purchase and ship • Up to 1,700 cy available • Some potential for low permeability (49% passing #200)	• Limited supply
4	Blue Clay	• Good price • Most likely the best low permeability material (~90% passing #200)	• Available only in piece-meal fashion, unless stockpiled at site over longer period of time
5	Progressive Number 2	• Sufficient quantity • OK price	• Too much sand (41%) and gravel (18%) so very likely not a good low permeability material • Furthest from site (distance)
6	Gunlock L & M Clay	• Most likely a good low permeability material (64% passing #200)	• Most likely insufficient quantity <5,000 cy) for cover • Highest cost to purchase and deliver • Most time to deliver (steep and winding dirt road to borrow area)
7	Gunlock Desert Sage	• Sufficient quantity	• Too much sand (68%) • Very likely not a low permeability material • High purchase and delivery price

Appendix C

HELP Modeling Results

Appendix C - HELP Modeling Results

Background

Water balance analyses of three closure plan cover system alternatives were performed for Pond 2 at Hecla's Apex facility located near St. George, Utah. The most recent Hydrologic Evaluation of Landfill Performance (HELP) model, version 3.07 (Schroeder 1994a and 1994b) (UASCE 1997) was utilized as the analytical model. The HELP model is a quasi-two-dimensional hydrologic model which accounts for effects of:

- surface water storage
- snowmelt
- runoff
- infiltration
- evapotranspiration
- vegetative growth
- soil moisture storage
- lateral subsurface drainage
- unsaturated vertical drainage
- various soil covers

The model was developed specifically to conduct water balance analyses of landfills, cover systems, and solid waste disposal / containment facilities and assists in comparison of design alternatives.

It is noted that research has shown that HELP overestimates vertical moisture flux (percolation) in arid and semi-arid climates as it does not closely account for capillary forces and does not allow for removal of water from below the soil evaporative zone (Fleenor and King 1995). As climate conditions become increasingly arid, consistently greater over-prediction of vertical moisture flux occurs in the model. Therefore, actual percolation at the Apex Site will likely be significantly less that those shown through this modeling effort, and HELP results shown here should only be utilized for comparison of different cover system alternatives.

The Final Closure Plan cover alternatives that were evaluated are listed in Table 1 on the following page. Hecla's selected alternative for the Final Closure Plan is listed as GCL (number 2).

Table 1 Conceptual Closure Plan Alternatives			
Cover System Layer	Alternative		
	1 Blue Clay (CCL)	2 GCL	3 On-Site Materials I
Surface	6" rock (outslopes only)	6" rock (outslopes only)	6" rock (outslopes only)
Protection	12" on-site soils TP-1 (2.6×10^{-6} cm/sec)	12" on-site soils TP-1 (2.6×10^{-6} cm/sec)	12" soils Shivwit's Dam (6.3×10^{-6} cm/sec)
Barrier	12" Blue Clay (10^{-7} to 10^{-8} cm/sec)	GCL (5×10^{-9} cm/sec)	12" on-site soils TP-1 (2.6×10^{-6} cm/sec)

HELP Model - Soil Layer Information

The HELP model includes a database of default soil types. Information listed for each default soil type includes:

- description (either USDA and USCS or material type)
- porosity
- field-capacity
- wilting point
- saturated hydraulic conductivity

Little site-specific moisture retention data exists, therefore default HELP soil types were selected based on the results of existing site-specific field sampling and laboratory testing. Values for each variable for each cover system analyzed are listed in Table 2 on the following page.

Table 2
HELP Model Default Soil Types - Cover System Alternatives

Cover System Variable	Alternative 1 Blue Clay (CCL)	Alternative 2 GCL	Alternative 3 On-Site Materials I
Layer 1 – Surface (Vertical Percolation)			
Depth	8"	8"	8"
HELP Soil Type	#21 (gravel)	#21 (gravel)	#21 (gravel)
Saturated Hyd. Cond.[1]	3.0×10^{-1} cm/sec	3.0×10^{-1} cm/sec	3.0×10^{-1} cm/sec
Porosity (vol/vol)	0.397	0.397	0.397
Field Capacity (v/v)[2]	0.032	0.032	0.032
Wilting Point (v/v)[3]	0.013	0.013	0.013
Layer 2 – Protection (Lateral Drainage)			
Distance	300 feet	300 feet	300 feet
Slope	1%	1%	1%
Depth	12"	12"	12"
HELP Soil Type	#25 (CL comp.[4])	#25 (CL comp.)	#23 (ML comp.)
Saturated Hyd. Cond.	3.6×10^{-6} cm/sec	3.6×10^{-6} cm/sec	9.0×10^{-6} cm/sec
Porosity (vol/vol)	0.437	0.437	0.461
Field Capacity (v/v)	0.373	0.373	0.360
Wilting Point (v/v)	0.266	0.266	0.203
Layer 3 – Barrier (Barrier Soil)			
Depth	12"	0.25"	12"
HELP Soil Type	#16 (barrier soil)	#17 (bentonite mat)	#25 (CL comp.)
Saturated Hyd. Cond.	1.0×10^{-7} cm/sec	3.0×10^{-9} cm/sec	3.6×10^{-6} cm/sec
Porosity (vol/vol)	0.427	0.750	0.437
Field Capacity (v/v)	0.418	0.747	0.373
Wilting Point (v/v)	0.367	0.400	0.266

1 - Saturated Hyd. Cond. = saturated hydraulic conductivity
2 - Field Capacity = moisture content at -1/3 bar
3 - Wilting Point = moisture content at -15 bars
4 - comp. = compacted

During initial HELP model runs, the program was utilized to calculate a Soil Conservation Service (SCS) curve number (89). For subsequent model runs, the curve number was set at 70. A curve number of 70 is analogous to pasture or range in poor condition and hydrologic soil group A. Group A soils have low total surface runoff potential due to high infiltration rates even when thoroughly wetted.

Climate

In order to provide climate data for the HELP model, a climate file was created from default data adjusted to site-specific values. A 5-year climate database was developed based on utilizing HELP's internal default information from its nearest climate station (Cedar City, Utah). This data was then adjusted for the climate data station (Lytle Ranch, Utah) nearest to the site. In particular the following data was utilized as input:

- Synthetic Precipitation - The input average annual precipitation was a conservative 10.71 inches which is significantly higher than St. George's average annual rainfall of 8.3 inches.
- Synthetic Temperature
- Synthetic Solar Radiation – Latitude was adjusted from 37.5 degrees to 37.1 degrees.
- Evaporative Zone Depth – Depth was set to default value for Cedar City (16 inches).
- Leaf Area Index – Index was set to zero for bare ground conditions.

A summary of daily temperature values and average annual precipitation for selected climate stations and values used in the HELP model is provided in Table 3 below.

Table 3
Summary of Temperature and Precipitation Data

	St. George, Utah[1]			Lytle Ranch, Utah[2]			HELP Model[3]	
Month	Daily Max. Temp (F)	Daily Min. Temp (F)	Avg. Precip. (inches)	Daily Max. Temp. (F)	Daily Min. Temp. (F)	Avg. Precip. (inches)	Average Daily Temp. (F)	Average Precipitation (inches)
Jan	53.5	25.6	1.09	56.9	29.0	1.71	43.0	1.71
Feb	60.0	30.4	0.99	61.0	33.1	2.03	47.1	2.03
Mar	67.8	36.0	0.94	68.0	37.5	1.74	52.8	1.74
Apr	76.7	42.8	0.51	76.7	42.0	0.60	59.4	0.60
May	86.0	50.9	0.40	85.2	49.0	0.52	67.1	0.52
Jun	96.1	58.9	0.19	94.5	55.2	0.35	74.9	0.35
Jul	101.6	66.3	0.68	100.7	60.6	0.65	80.7	0.65
Aug	99.5	65.0	0.77	99.7	60.0	0.74	79.9	0.74
Sep	92.6	55.1	0.62	92.4	52.4	0.73	72.4	0.73
Oct	80.2	43.0	0.68	80.3	41.6	0.64	61.0	0.64
Nov	64.9	31.8	0.63	65.6	31.6	0.65	48.6	0.65
Dec	54.0	25.7	0.77	57.3	26.5	0.36	41.9	0.36
Annual	**77.7**	**44.3**	**8.27**	**78.2**	**43.2**	**10.71**	--	--

1 St. George station operational from 1892 to 2001.
2 Lytle Ranch operational from 1988 to 2001 (WRCC, 2003).
3 HELP model precipitation and average daily temperature are from Lytle Ranch. Average daily temperature is the average of daily minimum and maximum values.

HELP Modeling Summary

The latest version (3.07) of the HELP model was utilized to evaluate three cover system alternatives. Results are summarized in Table 4 below.

Table 4
HELP Modeling Results Summary
Average Annual Totals - Years 1 to 5

Calculated HELP Values	Alternative		
	1 Blue Clay (CCL)	2 GCL	3 On-Site Materials I
Precipitation (inches/year)	10.82	10.82	10.82
Runoff (inches/year)	0.00	0.00	0.00
Evapotranspiration (inches/year)	10.06	10.08	10.49
Lateral Drainage Collected from Layer 2 (inches/year)	0.0565	0.1134	0.0000
Percolation/Leakage through layer 3 (inches/year)	0.62456	0.51796	0.22851
Average head on top of layer 3 (inches)	1.473	3.250	0.001
Change in water storage (inches)	0.083	0.112	0.103

Results from the HELP modeling show that:

- All three cover alternatives have very low and similar percolation rates, although comparatively, Alternative 3 would allow significantly less percolation than Alternatives 1 and 2.
- Alternatives 1 and 2 (Blue Clay and GCL) would have essentially the same percolation rates.
- Increases in water storage values would be nearly equivalent for all three alternatives.
- Total available water storage (the difference between field capacity and wilting point multiplied by the layer thickness) in the lower two (soil) layers for Alternatives 1 and 2 would be very similar. Total available water storage for Alternative 3 would be significantly higher as the Barrier Layer for Alternative 3 consists of a 12-inch thick layer of soil with a relatively open soil structure.
- Alternative 3 (On-Site Materials I) has the lowest percolation rate through the Barrier Layer, again due to the open soil structure and higher total available water storage capacity. The Barrier Layer for Alternative 3 consists of a 12-inch thick layer of soil type #25 (USCS type CL). The Barrier Layers for

Alternatives 1 and 2 consist of 12-inches of Blue Clay alternative and 0.25-inches of "Bentonite Mat", each of which has significantly less water storage capacity.

- Alternative 3 (On-Site Materials I) has the lowest average annual infiltration value (highest evapotranspiration). This is also due to the greater available water storage of the Barrier Layer material in this alternative.

Complete HELP modeling outputs are included after the References section.

References

Fleenor and King 1995. Fleenor, W. E., and King, I. P. Identifying Limitations on Use of HELP Model, Landfill Closures: Environmental Protection and Land Recovery, Special Publication #53, ASCE, Dunn, R. J. and Singh, U. P. editors.

Schroeder 1994a. Schroeder, P.R., Lloyd, C.M., and Zappi, P.A. The Hydrologic Evaluation of Landfill Performance (HELP) Model User's Guide for Version 3, EPA/600/R-94/168a, U.S. Environmental Protection Agency Risk Reduction Engineering Laboratory, Cincinnati, OH.

Schroeder 1994b. Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L. The Hydrologic Evaluation of Landfill Performance (HELP) Model; Engineering Documentation for Version 3, EPA/600/R-94/168b, U.S. Environmental Protection Agency Risk Reduction Engineering Laboratory, Cincinnati, OH.

USACE 1997. U.S. Army Corps of Engineers. Hydrologic Evaluation of Landfill Performance, Version 3.07. Environmental Laboratory, Waterways Experiment Station, Vicksburg, Mississippi 39180.

WRCC 2003. Western Regional Climate Center. Historical Climate Information, Desert Research Institute, Reno, Nevada. www.wrcc.dri.edu

HELP Output

Alternative Cover System 2

GCL

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.07   (1 NOVEMBER 1997)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:      C:\EPAHELPV\DATA4.D4
TEMPERATURE DATA FILE:        C:\EPAHELPV\DATA7.D7
SOLAR RADIATION DATA FILE:    C:\EPAHELPV\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\EPAHELPV\DATA11.D11
SOIL AND DESIGN DATA FILE:    C:\EPAHELPV\GCL.D10
OUTPUT DATA FILE:             C:\EPAHELPV\gcl.OUT

TIME: 11:56       DATE:  3/30/2003

******************************************************************************

     TITLE: APEX Cover Evaluation GCL Alternative

******************************************************************************

    NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                               LAYER  1
                               --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  21
          THICKNESS                  =     8.00    INCHES
          POROSITY                   =     0.3970 VOL/VOL
          FIELD CAPACITY             =     0.0320 VOL/VOL
          WILTING POINT              =     0.0130 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.0273 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =   0.300000012000     CM/SEC


                               LAYER  2
                               --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  25
          THICKNESS                  =    12.00    INCHES
          POROSITY                   =     0.4370 VOL/VOL
          FIELD CAPACITY             =     0.3730 VOL/VOL
          WILTING POINT              =     0.2660 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.3232 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =   0.359999990000E-05 CM/SEC
          SLOPE                      =     1.00    PERCENT
          DRAINAGE LENGTH            =   300.0     FEET
```

LAYER 3

TYPE 3 - **BARRIER SOIL LINER**
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	70.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	5.700	ACRES
EVAPORATIVE ZONE DEPTH	=	16.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.604	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.672	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.232	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	4.284	INCHES
TOTAL INITIAL WATER	=	4.284	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CEDAR CITY UTAH

STATION LATITUDE	=	37.10	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	125	
END OF GROWING SEASON (JULIAN DATE)	=	284	
EVAPORATIVE ZONE DEPTH	=	16.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.80	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	36.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	34.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MILFORD UTAH

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.71	2.03	1.74	0.60	0.52	0.35
0.65	0.74	0.73	0.64	0.65	0.36

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CEDAR CITY UTAH

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
43.00	47.10	52.80	59.40	67.10	74.90
80.70	79.90	72.40	61.00	48.60	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CEDAR CITY UTAH
AND STATION LATITUDE = 37.10 DEGREES

****

ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	8.97	185598.281	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	8.504	175961.437	94.81
DRAINAGE COLLECTED FROM LAYER 2	0.0003	7.089	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.237115	4906.151	2.64
AVG. HEAD ON TOP OF LAYER 3	1.3743		
CHANGE IN WATER STORAGE	0.228	4723.678	2.55
SOIL WATER AT START OF YEAR	4.284	88633.469	
SOIL WATER AT END OF YEAR	4.512	93357.148	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.072	0.00

****

ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.03	248912.781	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	10.725	221906.250	89.15
DRAINAGE COLLECTED FROM LAYER 2	0.4008	8292.013	3.33
PERC./LEAKAGE THROUGH LAYER 3	0.664916	13757.773	5.53
AVG. HEAD ON TOP OF LAYER 3	4.2542		
CHANGE IN WATER STORAGE	0.240	4956.729	1.99
SOIL WATER AT START OF YEAR	4.512	93357.148	

SOIL WATER AT END OF YEAR	4.752	98313.875	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.001	0.00

****

ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	11.70	242084.672	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	10.754	222504.437	91.91
DRAINAGE COLLECTED FROM LAYER 2	0.1034	2138.912	0.88
PERC./LEAKAGE THROUGH LAYER 3	0.771793	15969.175	6.60
AVG. HEAD ON TOP OF LAYER 3	4.9517		
CHANGE IN WATER STORAGE	0.071	1472.181	0.61
SOIL WATER AT START OF YEAR	4.752	98313.875	
SOIL WATER AT END OF YEAR	4.823	99786.062	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.048	0.00

****

ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	8.17	169045.531	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	8.031	166173.187	98.30
DRAINAGE COLLECTED FROM LAYER 2	0.0004	9.214	0.01
PERC./LEAKAGE THROUGH LAYER 3	0.304574	6301.935	3.73
AVG. HEAD ON TOP OF LAYER 3	1.7875		
CHANGE IN WATER STORAGE	-0.166	-3438.768	-2.03
SOIL WATER AT START OF YEAR	4.823	99786.062	

SOIL WATER AT END OF YEAR	4.656	96347.289	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.043	0.00

****

ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.25	274155.781	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	12.388	256318.766	93.49
DRAINAGE COLLECTED FROM LAYER 2	0.0622	1287.427	0.47
PERC./LEAKAGE THROUGH LAYER 3	0.611392	12650.315	4.61
AVG. HEAD ON TOP OF LAYER 3	3.8823		
CHANGE IN WATER STORAGE	0.188	3899.275	1.42
SOIL WATER AT START OF YEAR	4.656	96347.289	
SOIL WATER AT END OF YEAR	4.845	100246.562	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.005	0.00

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.42	1.55	1.41	0.81	0.75	0.39
	0.60	0.79	1.25	0.49	1.00	0.35
STD. DEVIATIONS	0.93	0.83	0.52	0.45	0.59	0.09
	0.52	0.40	0.73	0.45	0.61	0.21
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.901	1.440	1.329	1.115	0.719	0.355
	0.654	0.619	1.160	0.678	0.670	0.439
STD. DEVIATIONS	0.555	0.431	0.815	0.648	0.572	0.160
	0.600	0.305	0.597	0.349	0.569	0.213
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0202	0.0185	0.0088	0.0037	0.0001	0.0001
	0.0000	0.0000	0.0000	0.0001	0.0619	0.0001
STD. DEVIATIONS	0.0357	0.0367	0.0194	0.0081	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.1383	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0403	0.0646	0.0692	0.0592	0.0451	0.0351
	0.0304	0.0254	0.0255	0.0357	0.0479	0.0394
STD. DEVIATIONS	0.0387	0.0474	0.0442	0.0300	0.0193	0.0134
	0.0119	0.0098	0.0139	0.0187	0.0381	0.0266

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3						
AVERAGES	2.9841	5.4253	5.2299	4.5860	3.3172	2.6154
	2.1547	1.7561	1.8342	2.5742	3.6578	2.8651
STD. DEVIATIONS	2.9947	4.1050	3.4790	2.4461	1.5265	1.0933
	0.9373	0.7738	1.1315	1.4790	3.1117	2.1034

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES		CU. FEET	PERCENT
PRECIPITATION	10.82	(2.156)	223959.4	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	10.080	(1.7942)	208572.83	93.130
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.11343	(0.16646)	2346.931	1.04793
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.51796	(0.23407)	10717.069	4.78527
AVERAGE HEAD ON TOP OF LAYER 3	3.250	(1.578)		
CHANGE IN WATER STORAGE	0.112	(0.1693)	2322.62	1.037

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	0.97	20070.270
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 2	0.07468	1545.21692
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.005510	114.00568
AVERAGE HEAD ON TOP OF LAYER 3	13.249	
MAXIMUM HEAD ON TOP OF LAYER 3	16.286	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	125.2 FEET	
SNOW WATER	0.08	1661.7969
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2798	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1397	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	0.1163	0.0145
2	4.5411	0.3784
3	0.1875	0.7500
SNOW WATER	0.000	

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****

HELP Output

Alternative Cover System 1

Blue Clay

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:      C:\EPAHELPV\DATA4.D4
TEMPERATURE DATA FILE:        C:\EPAHELPV\DATA7.D7
SOLAR RADIATION DATA FILE:    C:\EPAHELPV\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\EPAHELPV\DATA11.D11
SOIL AND DESIGN DATA FILE:    C:\EPAHELPV\BLUECLAY.D10
OUTPUT DATA FILE:             C:\EPAHELPV\blueclay.OUT

TIME:  11:51      DATE:   3/30/2003

******************************************************************************
             TITLE:  APEX Cover Evaluation Blue Clay
******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  21
          THICKNESS                  =     8.00    INCHES
          POROSITY                   =     0.3970 VOL/VOL
          FIELD CAPACITY             =     0.0320 VOL/VOL
          WILTING POINT              =     0.0130 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.0273 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC


                                  LAYER  2
                                  --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  25
          THICKNESS                  =    12.00    INCHES
          POROSITY                   =     0.4370 VOL/VOL
          FIELD CAPACITY             =     0.3730 VOL/VOL
          WILTING POINT              =     0.2660 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.3232 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.359999990000E-05 CM/SEC
          SLOPE                      =     1.00    PERCENT
          DRAINAGE LENGTH            =   300.0     FEET
```

LAYER 3

TYPE 3 - **BARRIER SOIL LINER**
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	70.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	5.700	ACRES
EVAPORATIVE ZONE DEPTH	=	16.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.604	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.672	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.232	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	9.220	INCHES
TOTAL INITIAL WATER	=	9.220	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CEDAR CITY UTAH

STATION LATITUDE	=	37.10	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	125	
END OF GROWING SEASON (JULIAN DATE)	=	284	
EVAPORATIVE ZONE DEPTH	=	16.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.80	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	36.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	34.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MILFORD UTAH

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.71	2.03	1.74	0.60	0.52	0.35
0.65	0.74	0.73	0.64	0.65	0.36

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CEDAR CITY UTAH

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
43.00	47.10	52.80	59.40	67.10	74.90
80.70	79.90	72.40	61.00	48.60	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CEDAR CITY UTAH
AND STATION LATITUDE = 37.10 DEGREES

****

ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	8.97	185598.281	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	8.504	175961.437	94.81
DRAINAGE COLLECTED FROM LAYER 2	0.0001	1.548	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.268053	5546.291	2.99
AVG. HEAD ON TOP OF LAYER 3	0.3012		
CHANGE IN WATER STORAGE	0.198	4089.082	2.20
SOIL WATER AT START OF YEAR	9.220	190774.594	
SOIL WATER AT END OF YEAR	9.418	194863.672	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.074	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.03	248912.781	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	10.725	221906.250	89.15
DRAINAGE COLLECTED FROM LAYER 2	0.2813	5820.932	2.34
PERC./LEAKAGE THROUGH LAYER 3	0.903545	18695.254	7.51
AVG. HEAD ON TOP OF LAYER 3	2.6175		
CHANGE IN WATER STORAGE	0.120	2490.317	1.00

SOIL WATER AT START OF YEAR	9.418	194863.672	
SOIL WATER AT END OF YEAR	9.538	197353.984	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.014	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	11.70	242084.672	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	10.706	221513.750	91.50
DRAINAGE COLLECTED FROM LAYER 2	0.0005	11.036	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.958710	19836.670	8.19
AVG. HEAD ON TOP OF LAYER 3	2.1747		
CHANGE IN WATER STORAGE	0.035	723.235	0.30
SOIL WATER AT START OF YEAR	9.538	197353.984	
SOIL WATER AT END OF YEAR	9.573	198077.219	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.035	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	8.17	169045.531	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	8.029	166119.531	98.27
DRAINAGE COLLECTED FROM LAYER 2	0.0001	1.865	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.291976	6041.267	3.57
AVG. HEAD ON TOP OF LAYER 3	0.3601		
CHANGE IN WATER STORAGE	-0.151	-3117.139	-1.84
SOIL WATER AT START OF YEAR	9.573	198077.219	

SOIL WATER AT END OF YEAR	9.422	194960.078	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.002	0.00

****

ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.25	274155.781	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	12.336	255251.297	93.10
DRAINAGE COLLECTED FROM LAYER 2	0.0005	9.708	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.700508	14494.208	5.29
AVG. HEAD ON TOP OF LAYER 3	1.9112		
CHANGE IN WATER STORAGE	0.213	4400.559	1.61
SOIL WATER AT START OF YEAR	9.422	194960.078	
SOIL WATER AT END OF YEAR	9.635	199360.641	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.005	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.42	1.55	1.41	0.81	0.75	0.39
	0.60	0.79	1.25	0.49	1.00	0.35
STD. DEVIATIONS	0.93	0.83	0.52	0.45	0.59	0.09
	0.52	0.40	0.73	0.45	0.61	0.21
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.901	1.437	1.320	1.113	0.718	0.355
	0.654	0.619	1.156	0.678	0.670	0.439
STD. DEVIATIONS	0.555	0.431	0.805	0.647	0.571	0.159
	0.599	0.305	0.591	0.349	0.569	0.213
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0122	0.0008	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0433	0.0000
STD. DEVIATIONS	0.0272	0.0016	0.0001	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0968	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0363	0.0833	0.1107	0.1082	0.0888	0.0401
	0.0045	0.0013	0.0112	0.0457	0.0541	0.0403
STD. DEVIATIONS	0.0635	0.0786	0.0739	0.0609	0.0536	0.0504
	0.0082	0.0011	0.0215	0.0632	0.0720	0.0641

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ON TOP OF LAYER 3						
AVERAGES	1.2734	4.0184	4.0560	3.0650	1.2671	0.3041
	0.0051	0.0001	0.1198	0.6888	1.7967	1.0806
STD. DEVIATIONS	2.0605	3.8876	3.3014	2.4168	1.2680	0.4968
	0.0112	0.0001	0.2672	1.2071	3.2751	2.3619

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES		CU. FEET	PERCENT
PRECIPITATION	10.82	(2.156)	223959.4	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	10.060	(1.7740)	208150.47	92.941
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.05650	(0.12568)	1169.018	0.52198
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.62456	(0.32900)	12922.737	5.77012
AVERAGE HEAD ON TOP OF LAYER 3	1.473	(1.073)		
CHANGE IN WATER STORAGE	0.083	(0.1485)	1717.21	0.767

PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	0.97	20070.270
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 2	0.05849	1210.12781
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.007081	146.51971
AVERAGE HEAD ON TOP OF LAYER 3	12.982	
MAXIMUM HEAD ON TOP OF LAYER 3	15.989	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	124.1 FEET	
SNOW WATER	0.08	1661.7969

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2731
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1397

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	0.1163	0.0145
2	4.3948	0.3662
3	5.1240	0.4270
SNOW WATER	0.000	

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HELP Output

Alternative Cover System 3

On-Site Materials I

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******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07   (1 NOVEMBER 1997)               **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:      C:\EPAHELPV\DATA4.D4
TEMPERATURE DATA FILE:        C:\EPAHELPV\DATA7.D7
SOLAR RADIATION DATA FILE:    C:\EPAHELPV\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\EPAHELPV\DATA11.D11
SOIL AND DESIGN DATA FILE:    C:\EPAHELPV\ONSITE.D10
OUTPUT DATA FILE:             C:\EPAHELPV\onsite.OUT

TIME:  11:58      DATE:   3/30/2003

******************************************************************************
   TITLE:  APEX Cover Evaluation On-Site Materials Alternative
******************************************************************************
     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                LAYER  1
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  21
          THICKNESS                  =       8.00    INCHES
          POROSITY                   =       0.3970 VOL/VOL
          FIELD CAPACITY             =       0.0320 VOL/VOL
          WILTING POINT              =       0.0130 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0.0241 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =   0.300000012000     CM/SEC


                                LAYER  2
                                --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER  23
          THICKNESS                  =      12.00    INCHES
          POROSITY                   =       0.4610 VOL/VOL
          FIELD CAPACITY             =       0.3600 VOL/VOL
          WILTING POINT              =       0.2030 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0.2736 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =   0.900000032000E-05 CM/SEC
          SLOPE                      =       1.00    PERCENT
          DRAINAGE LENGTH            =     300.0     FEET
```

LAYER 3

TYPE 3 - **BARRIER SOIL LINER**
MATERIAL TEXTURE NUMBER 25

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.3730	VOL/VOL
WILTING POINT	=	0.2660	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.359999990000E-05	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	70.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	5.700	ACRES
EVAPORATIVE ZONE DEPTH	=	16.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.036	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.864	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.728	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	8.720	INCHES
TOTAL INITIAL WATER	=	8.720	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CEDAR CITY UTAH

STATION LATITUDE	=	37.10	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	125	
END OF GROWING SEASON (JULIAN DATE)	=	284	
EVAPORATIVE ZONE DEPTH	=	16.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.80	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	36.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	34.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MILFORD UTAH

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.71	2.03	1.74	0.60	0.52	0.35
0.65	0.74	0.73	0.64	0.65	0.36

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CEDAR CITY UTAH

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
43.00	47.10	52.80	59.40	67.10	74.90
80.70	79.90	72.40	61.00	48.60	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CEDAR CITY UTAH
AND STATION LATITUDE = 37.10 DEGREES

****

ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	8.97	185598.281	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	8.886	183852.016	99.06
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.002411	49.878	0.03
AVG. HEAD ON TOP OF LAYER 3	0.0000		
CHANGE IN WATER STORAGE	0.082	1696.401	0.91
SOIL WATER AT START OF YEAR	8.720	180416.891	
SOIL WATER AT END OF YEAR	8.802	182113.297	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.014	0.00

****

ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.03	248912.781	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	11.364	235129.812	94.46
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.036	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.807184	16701.451	6.71
AVG. HEAD ON TOP OF LAYER 3	0.0035		

CHANGE IN WATER STORAGE	-0.141	-2918.591	-1.17
SOIL WATER AT START OF YEAR	8.802	182113.297	
SOIL WATER AT END OF YEAR	8.661	179194.703	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.059	0.00

****

ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	11.70	242084.672	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	11.140	230502.172	95.22
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.018862	390.266	0.16
AVG. HEAD ON TOP OF LAYER 3	0.0001		
CHANGE IN WATER STORAGE	0.541	11192.160	4.62
SOIL WATER AT START OF YEAR	8.661	179194.703	
SOIL WATER AT END OF YEAR	9.201	190386.875	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.062	0.00

****

ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	8.17	169045.531	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	8.408	173965.109	102.91
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.008979	185.785	0.11

AVG. HEAD ON TOP OF LAYER 3	0.0000		
CHANGE IN WATER STORAGE	-0.247	-5105.501	-3.02
SOIL WATER AT START OF YEAR	9.201	190386.875	
SOIL WATER AT END OF YEAR	8.955	185281.359	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.135	0.00

****

ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.25	274155.781	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	12.666	262068.219	95.59
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.004	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.305118	6313.189	2.30
AVG. HEAD ON TOP OF LAYER 3	0.0010		
CHANGE IN WATER STORAGE	0.279	5774.373	2.11
SOIL WATER AT START OF YEAR	8.955	185281.359	
SOIL WATER AT END OF YEAR	9.234	191055.734	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.006	0.00

****

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.42	1.55	1.41	0.81	0.75	0.39
	0.60	0.79	1.25	0.49	1.00	0.35
STD. DEVIATIONS	0.93	0.83	0.52	0.45	0.59	0.09
	0.52	0.40	0.73	0.45	0.61	0.21
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.824	1.537	1.553	0.983	0.733	0.386
	0.624	0.707	1.208	0.641	0.740	0.558
STD. DEVIATIONS	0.568	0.477	0.983	0.544	0.442	0.177
	0.650	0.470	0.638	0.283	0.631	0.188
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0138	0.1012	0.0113	0.0018	0.0010	0.0015
	0.0010	0.0004	0.0003	0.0000	0.0961	0.0001
STD. DEVIATIONS	0.0299	0.1381	0.0209	0.0021	0.0011	0.0027
	0.0009	0.0005	0.0005	0.0000	0.2139	0.0002

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ON TOP OF LAYER 3						
AVERAGES	0.0003	0.0038	0.0005	0.0001	0.0001	0.0001
	0.0001	0.0000	0.0000	0.0000	0.0061	0.0000
STD. DEVIATIONS	0.0005	0.0052	0.0009	0.0002	0.0001	0.0002
	0.0000	0.0000	0.0000	0.0000	0.0135	0.0000

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	10.82 (2.156)	223959.4	100.00
RUNOFF	0.000 (0.0000)	0.00	0.000
EVAPOTRANSPIRATION	10.493 (1.7910)	217103.47	96.939
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.00000 (0.00000)	0.008	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.22851 (0.34785)	4728.114	2.11115
AVERAGE HEAD ON TOP OF LAYER 3	0.001 (0.001)		
CHANGE IN WATER STORAGE	0.103 (0.3182)	2127.77	0.950

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	0.97	20070.270
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 2	0.00000	0.01386
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.126475	2616.90039
AVERAGE HEAD ON TOP OF LAYER 3	0.394	
MAXIMUM HEAD ON TOP OF LAYER 3	0.738	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	19.1 FEET	
SNOW WATER	0.08	1661.7969
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2446	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1103	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	0.1161	0.0145
2	3.8736	0.3228
3	5.2440	0.4370
SNOW WATER	0.000	

****
****

Appendix D

Vertical Wick Drain Analyses

Appendix D - Vertical Wick Drain Analyses

Background

Vertical wick drains are to be installed through the temporary cover materials and into the waste materials within Hecla's Pond 2 at the Apex Site. Analyses of the waste material's flow characteristics and the corresponding consolidation time were conducted to determine the estimated optimum spacing (quantity of drains) to be installed. Vertical drains facilitate the dewatering / consolidation process by providing a shorter and much higher permeability conduit for fluid flow from the waste materials. Providing for drainage / consolidation prior to final cover placement will minimize potential future settlement and long-term damage to the final cover system.

Method of Analysis

Optimum drain spacing is dependent on the flow characteristics of each material to be drained, which is primarily determined by that material's coefficient of horizontal flow (C_h) measured in m^2/sec. Additional factors for determining optimum drain spacing are:

- U = average degree of consolidation (%)
- t = the desired consolidation time

both of which are selected by the designer.

For these analyses the average degree of consolidation was selected as 90% and a range of times from 1 to 4 months was selected in which to achieve 90% consolidation.

Calculation of C_h

Ideally C_h is determined in the laboratory by first testing for and calculating the coefficient of vertical consolidation (C_v) from undisturbed material samples, then correlating the tested C_v value to a C_h value. Typically C_h ranges from 1 to 5 times the C_v value (Bowles 1982, NILEX 2003). At the Apex site C_v could not be determined in the laboratory as waste materials from the impoundment contained significant quantities of fine grained materials and fluids (see Table 1 on the following page).

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Consolidation time
up to 4 months - ?

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Table 1
Waste Material Field and Laboratory Testing Data

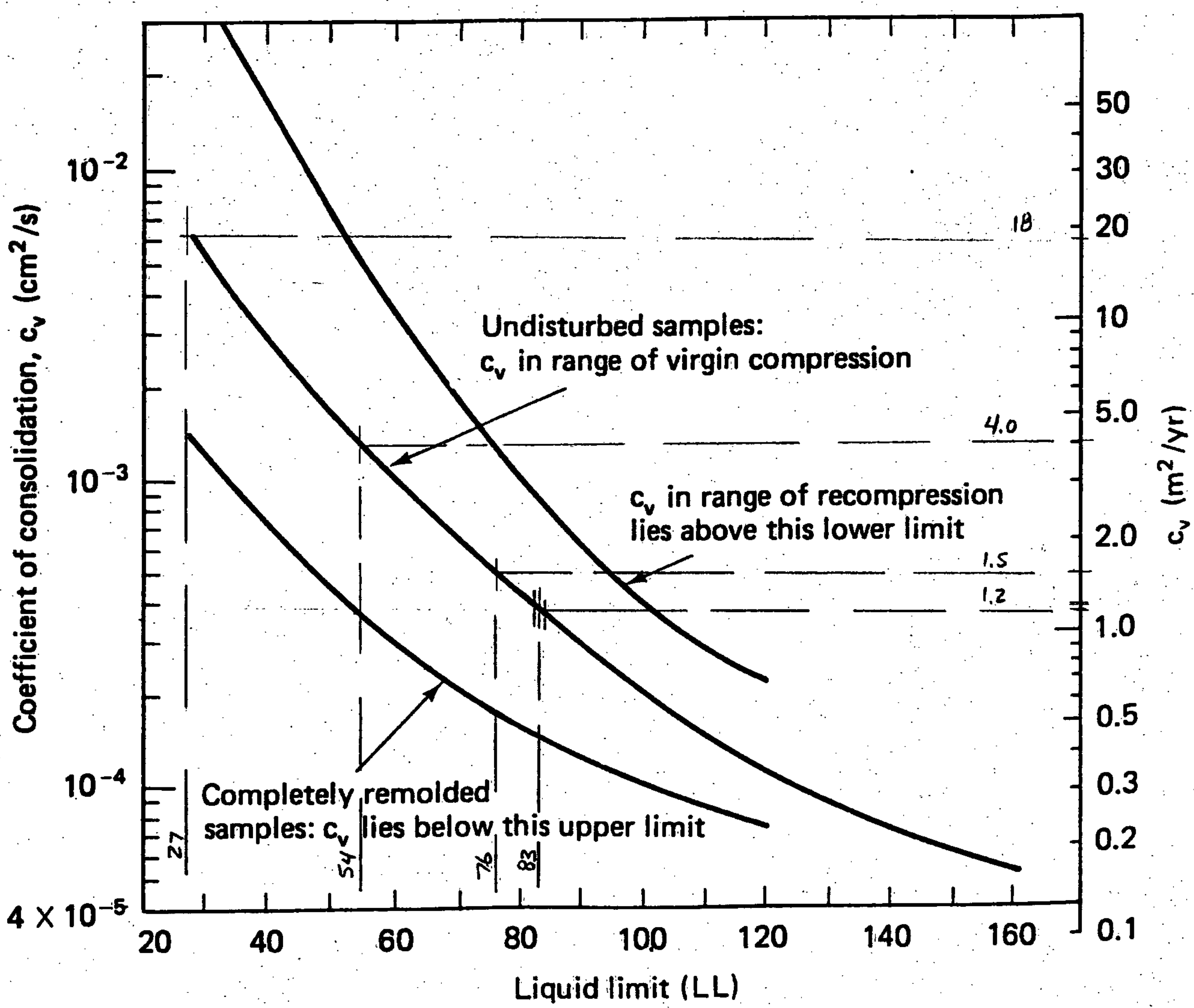
Bore Hole	Sample Number	Sample Depth (ft)	Moisture Content (%)	Percent Passing #200 Sieve	Liquid Limit
1	1	5 - 7	107.0	99.3	83
1	2	8.5 - 9	115.7	93.6	76
3	4	5.5 - 6	52.1	66.1	54
3	5	6.5 - 7	61.8	72.5	54
5	6	6 - 6.5	103.9	98.5	82
6	7	6.5 - 7	114.0	96.3	84
7	8	8 - 9	20.1	36.1	27

These very wet, high fines waste material samples could not be successfully sampled, transported, and have accurate laboratory consolidation tests conducted as significant remolding of the samples occurred between extraction from the impoundment and receipt at the laboratory. Therefore to determine C_v, a range of values was estimated by utilizing correlations between a known material characteristic (liquid limit) and C_v (U.S. Navy 1971) (Holtz and Kovacs 1981). The correlation chart between liquid limit values and C_v values is shown on the following page.

Based on the amount of coarse grained materials placed into the impoundment during clean-up activities (SMI 2001), a value of 3.5 was used as the correlation between C_v and C_h. Table 2 below shows the results from the correlation between liquid limit values, C_v, and C_h.

Table 2
C_h from Liquid Limits

Sample Number	Liquid Limit	C_v (undisturbed) (m^2/yr)	C_v (m^2/s)	C_h (m^2/sec)
1	83	1.2	3.8×10^{-8}	1.3×10^{-7}
2	76	1.5	4.8×10^{-8}	1.7×10^{-7}
4	54	4.0	1.3×10^{-7}	4.4×10^{-7}
5	54	4.0	1.3×10^{-7}	4.4×10^{-7}
6	82	1.2	3.8×10^{-8}	1.3×10^{-7}
7	84	1.2	3.8×10^{-8}	1.3×10^{-7}
8	27	18	5.7×10^{-7}	2.0×10^{-6}
			Average =	4.9×10^{-7}



Coefficient of consolidation, c_v (cm^2/s)
10^{-2}
10^{-3}
10^{-4}
4×10^{-5}
c_v (m^2/yr)
50
30
20
10
5.0
2.0
1.0
0.5
0.3
0.2
0.1
20
40
60
80
100
120
140
160
Liquid limit (LL)
Undisturbed samples:
c_v in range of virgin compression
c_v in range of recompression
lies above this lower limit
Completely remolded
samples: c_v lies below this upper limit
18
4.0
1.5
1.2
27
54
76
83

C_h values for individual samples were then used to estimate a range of representative C_h values for materials within the impoundment. The range selected was from 1.5×10^{-7} m²/sec to 4.5×10^{-7} m²/sec. These "slow" and "fast" C_h values, along with a U = 90%, were then used to calculate optimum wick drain spacing given a desired consolidation time of between 1 and 4 months.

Even though each of the correlations used in these analyses are approximate, they are as accurate as possible given the wide range of flow values likely present within the wastes. Based on results from previous remediation work and field investigations (SMI 2001) (Hecla 2001), waste materials within the impoundment are very heterogeneous and possess a wide range of grain size distributions, and therefore will have a significantly different C_v and C_h values (flow characteristics).

Calculated Drain Spacing

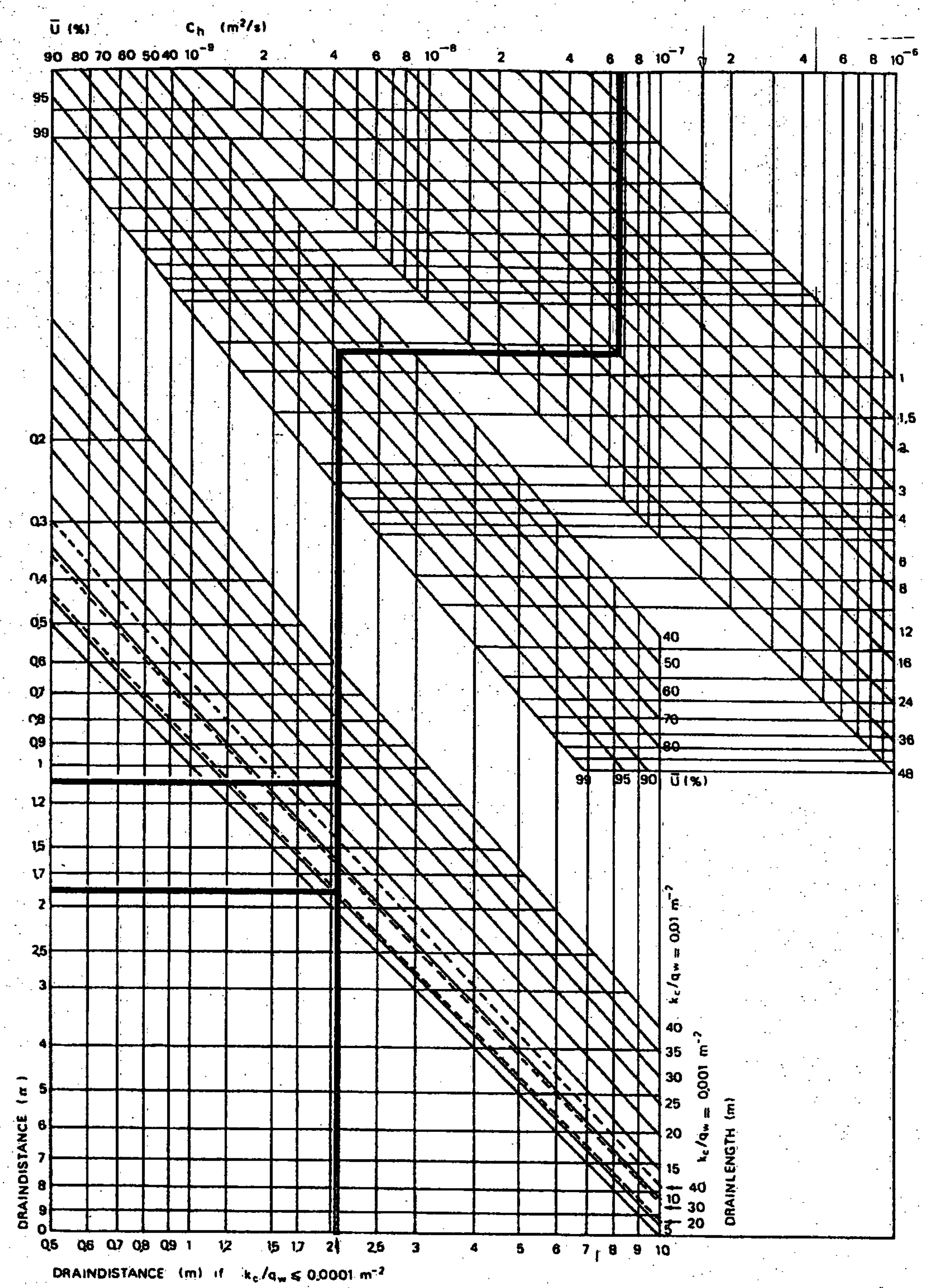
Using the estimated slow and fast C_h values of 1.5×10^{-7} m²/sec and 4.5×10^{-7} m²/sec, optimum drain spacing was calculated based on NILEX's design guide (NILEX 2003). Table 3 below shows the results. A copy of NILEX's Wick Design Spacing Graph is attached on the following page.

Table 3
Time vs. Drain Spacing

C_h (m²/sec)	Time to Consolidation (months)	Drain Spacing (m)	Drain Spacing (ft)
1.5×10^{-7}	1	0.8	2.6
	2	1.05	3.4
	3	1.25	4.1
	4	1.35	4.4
4.5×10^{-7}	1	1.25	4.1
	2	1.65	5.4
	3	2.0	6.6
	4	2.2	7.2

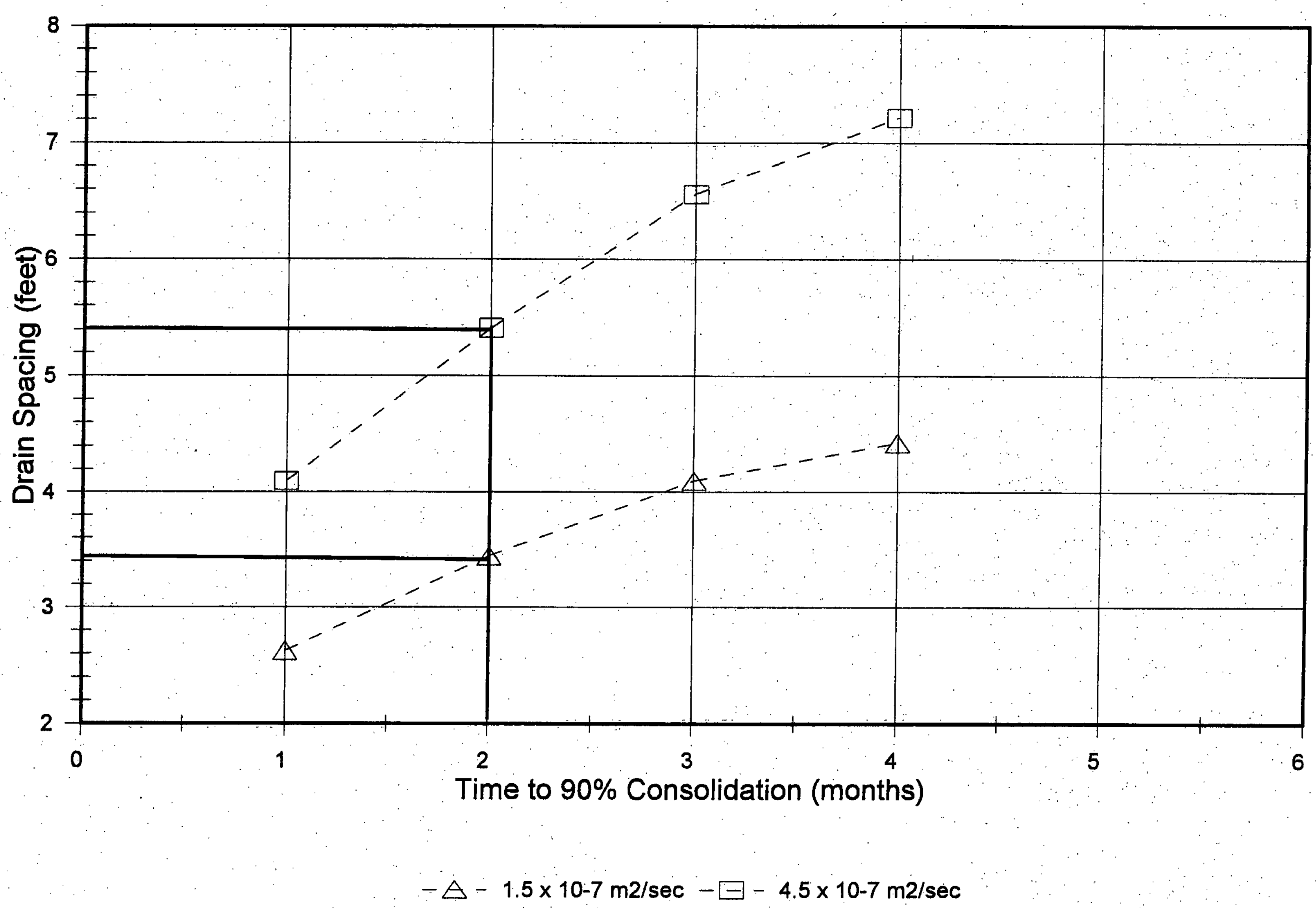
Average degree of consolidation U = 90%

Data from Table 3 above is shown graphically on the second page following. Given the two C_h rates, the graph shows that drain spacing of between approximately 3.4 and 5.4 feet is required to successfully drain / consolidate the waste materials in 2 months.



- Wick Drain Spacing Graph

Drain Spacing vs. Time



Monster Engineering Inc.

Drain Cost Estimate

Table 4 below contains cost estimate data for various drain spacing designs. Data in this table is based on the latest cost information from NILEX.

Table 4
Drain Spacing vs. Cost

Drain Spacing (ft)	Number of Drains Across[1]	Est. Drains/ Acre	Lineal Feet/ Acre[2] (ft)	Total Lineal Feet (ft)	Estimated Cost/Foot ($)	Total Cost ($)	Total Cost w/ Mob.[3] ($)
3	71	4,980	69,715	348,576	$0.40	$139,430	$154,430
4	53	2,828	39,586	197,931	$0.43	$85,110	$100,110
5	43	1,827	25,574	127,870	$0.46	$58,820	$73,820
6	36	1,280	17,926	89,631	$0.50	$44,816	$59,816
7	31	950	13,293	66,466	$0.52	$34,563	$49,563
8	27	734	10,272	51,361	$0.57	$29,276	$44,276
9	24	585	8,191	40,957	$0.60	$24,574	$39,574
10	22	478	6,696	33,481	$0.65	$21,763	$36,763

1 - Number of drains across one side of a 1 acre square assuming the given drain spacing.
2 - Based on estimated 14 foot depth for each drain.
3 - Mobilization = $15,000

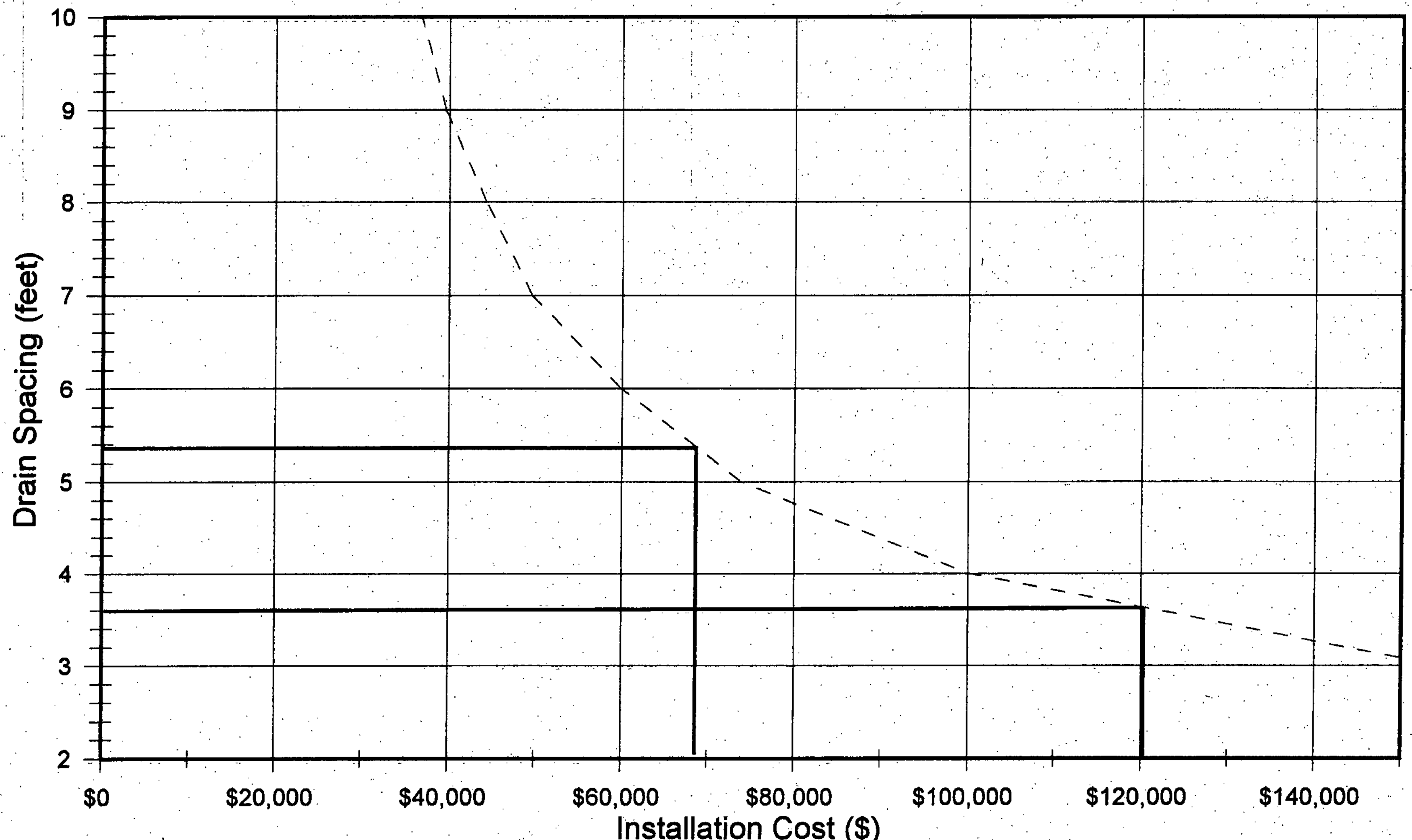
The graph on the following page plots data from Table 4 and shows estimated costs for any given drain spacing. As an example, the estimated installation cost for the required amount of drain material for a time of consolidation of 2 months (drain spacing of 3.4 to 5.4 feet) is between $68,000 to $120,000.

Summary

This analysis shows that based on laboratory testing results and estimated flow characteristics of the waste materials, a vertical wick drain spacing of approximately 3.4 to 5.4 feet is required in order to achieve 90% consolidation of the wastes in a period of approximately 2 months.

It is noted that preloading will increase the drains' effectiveness and will speed up the drainage / consolidation process. Based on Hecla's selected Final Closure Plan alternative, preloads will be added on top of the impoundment during embankment regrading.

Drain Spacing vs. Installation Cost



References

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SMI 2001. Shepherd Miller Inc. Soil Sampling and Analysis Work Plan, prepared for Hecla Mining Company for the Apex Unit, August 30, 2001.

U.S. Navy 1971. "Soil Mechanics, Foundations, and Earth Structures," *NAVFAC Design Manual DM-7*, Washington, D.C.

Appendix E

Stability Analyses

Appendix E – Stability Analyses

Background

Slope stability analyses utilizing version 5.204 of the XSTABL computer program were conducted on two separate impoundment embankment cross-sections for Pond 2 at Hecla Mining Company's Apex Site. The two sections analyzed included:

- post excavation of a portion of the existing embankment (designated the Excavated Section)
- after completion of the final cover system (designated the Reclaimed Section)

Excavated Section geometry was based removing sufficient existing embankment material to expose the existing impoundment liner, leaving an approximate 1:1 (H:V) backslope. Reclaimed Section geometry was based on a final reconstructed embankment configuration of 3.5:1 (H:V), including all layers of the Final Cover System as designed for the Final Closure Plan.

Material Properties

Material locations (zones) and properties were based on information collected from previous field work (SMI 2001, Hecla 2001, MEI 2003), laboratory testing (MEI 2003), and correlations to standard material properties for materials similar to the impoundment embankment, temporary cover, liner (EPA 1996), and wastes. Table 1 below provides soil unit numbers, descriptions, weights, and strength parameters utilized in the analyses. Individual soil units are indicated on the attached stability analysis geometry sections. Eight different soil units were utilized in the Reclaimed Section.

Table 1
Material Types and Properties

Soil Unit	Description	Moist Unit Weight (pcf)	Saturated Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg)
1	Rock Cover	130	135	0	40
2	Protection Layer	125	135	100	33
3	GCL[1]	90	100	290	25
4	Temporary Cover	115	125	50	38
5	Type IV Waste	65	68	200	20
6	Existing Embankment	120	130	50	38
7	Type I, II, and III Wastes	90	100	50	20
8	Reconstructed Embankment	120	130	200	30

Table Abbreviations: pcf – pounds per cubic foot
psf – pounds per square foot
deg – degrees
GCL – geocomposite clay liner

References: 1 – (Sharma 1994) - typical value for bentonite mat under free swell exposed to mild leachate
2 – (Bowles 1996) - conservative strength value for dense silty sand

Phreatic Surface

The fluid surface location (the phreatic surface) used in the stability analyses for both the Excavated and Reclaimed Sections are shown on the attached figures. The fluid surface was conservatively modeled to show saturated material conditions all the way to the outside edge of the Excavated Section. In general, the phreatic surface was located near the top of the Type IV Waste Material layer (at the bottom of the Temporary Cover Material), angled down towards the top of the existing embankment, turned sharply downward along the outer face of the remaining existing embankment, then downward away from the impoundment into the native soil layer.

Results - Excavated Section

The Excavated Section was analyzed utilizing a circular failure surface search routine with factors of safety calculated by the simplified Bishop method. One hundred (100) failure surfaces were analyzed and are shown on an attached figure. An additional figure shows the 10 most critical failure surfaces. The lowest factor of safety calculated for the Excavated Section was is 1.6. The factor of safety range for the 10 most critical failure surfaces was between 1.6 and 2.0.

Results - Reclaimed Section

A circular failure surface search routine using the simplified Bishop method was also used on the Reclaimed Section. One hundred (100) failure surfaces were analyzed (shown on an attached figure), with the 10 most critical failure surfaces shown seperately. The lowest factor of safety calculated for the Reclaimed Section was 4.1, and the factor of safety range for the 10 most critical surfaces was between 4.1 and 4.8.

Due to the bilinear geometry of the surface between the excavated slope and the reconstructed embankment, and the potential for slip-plane development in the GCL layer, a block failure search routine was also utilized to analyze the Reclaimed Section. Figures showing section geometry, the 100 failure surfaces analyzed, and the 10 most critical failure surfaces are attached. The lowest factor of safety calculated for the Reclaimed Section utilizing this block failure search routine was 4.5, and the factor of safety range for the 10 most critical failure surfaces was 4.5 to 4.9.

REFERENCES

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EPA 1996. Daniel, D.E. and Scranton, H.B. "Report of 1995 Workshop on Geosynthetic Clay Liners", National Risk Management Research Laboratory, Office of Research and Development, June 1996, EPA/600/R-96/149.

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MEI 2003. Monster Engineering Inc. Potential Borrow Source Materials Investigation; Apex Site – Hecla Mining Company, Technical Memorandum prepared for Chris Gypton, Hecla Mining Company, February 3, 2003.

Sharma 1994. Sharma, Hari D. and Lewis, S.P. "Waste Containment Systems, Waste Stabilization, and Landfills: Design and Evaluation." John Wiley & Sons, Inc, New York.

SMI 2001. Shephere Miller Inc. Soil Sampling and Analysis Work Plan, prepared for Hecla Mining Company for the Apex Unit, August 30, 2001.

Appendix E – Stability Analyses

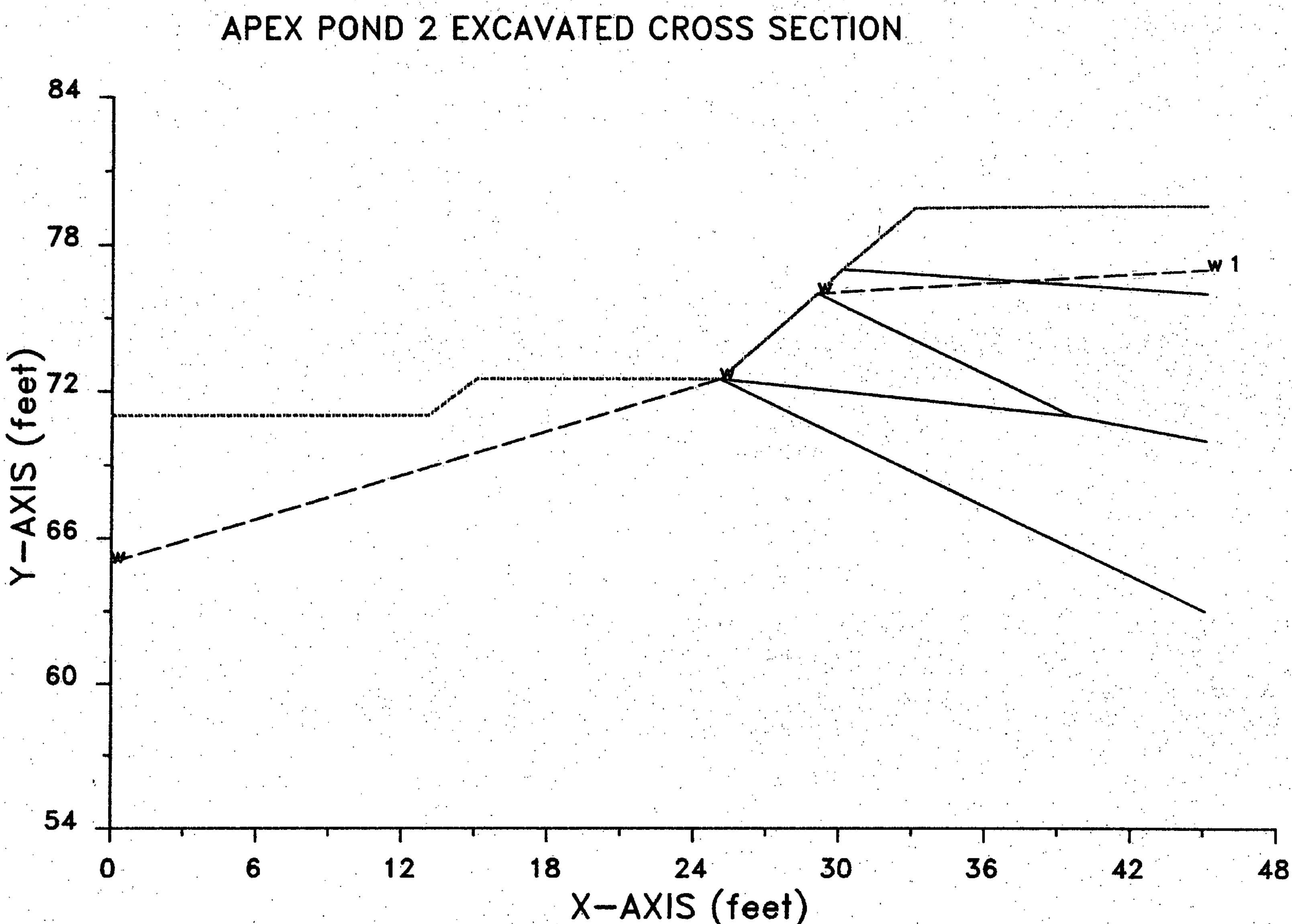
Section Plots and Analyses Outputs

XSTABL Output

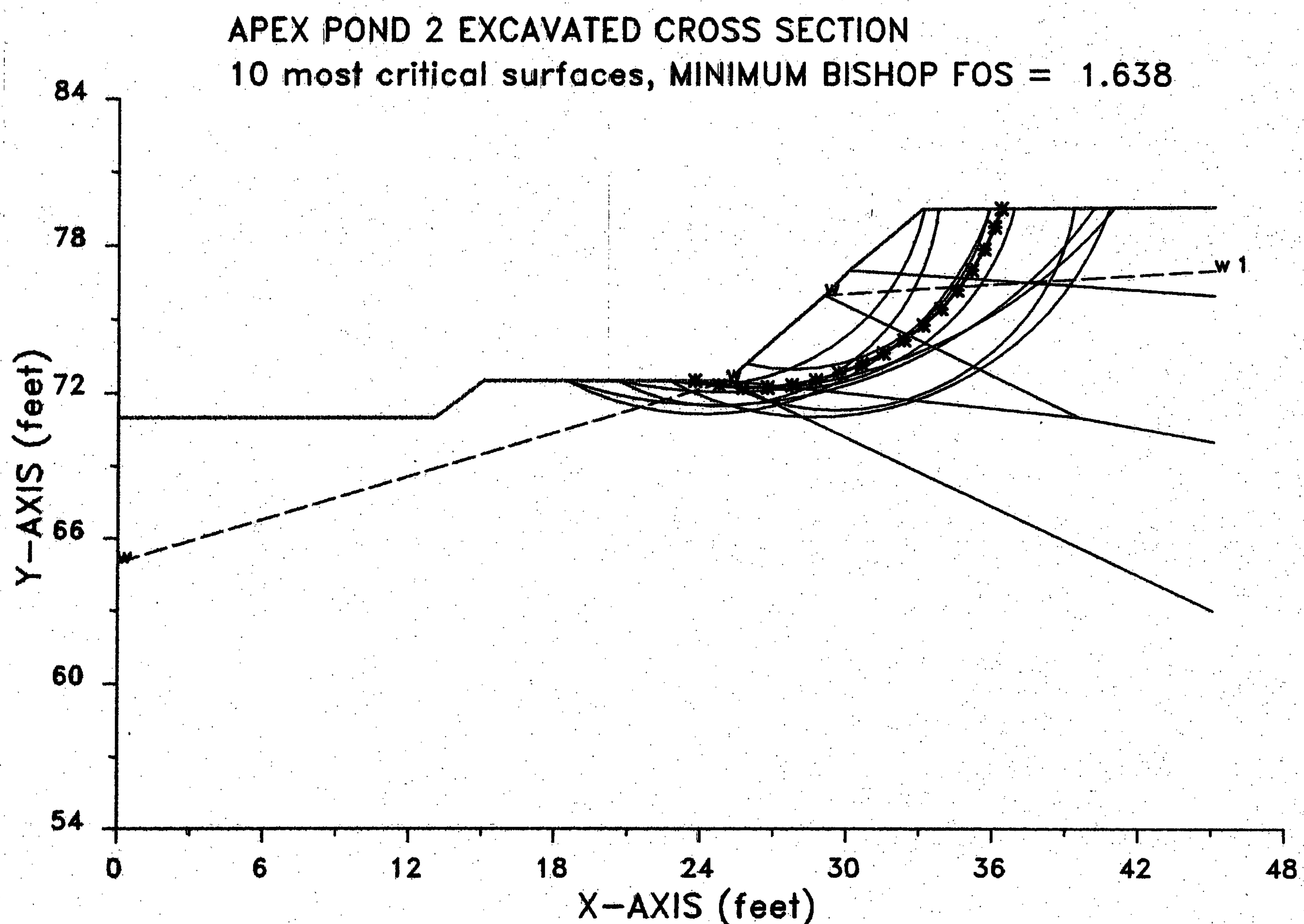
Excavated Section

Circular Failure Surfaces

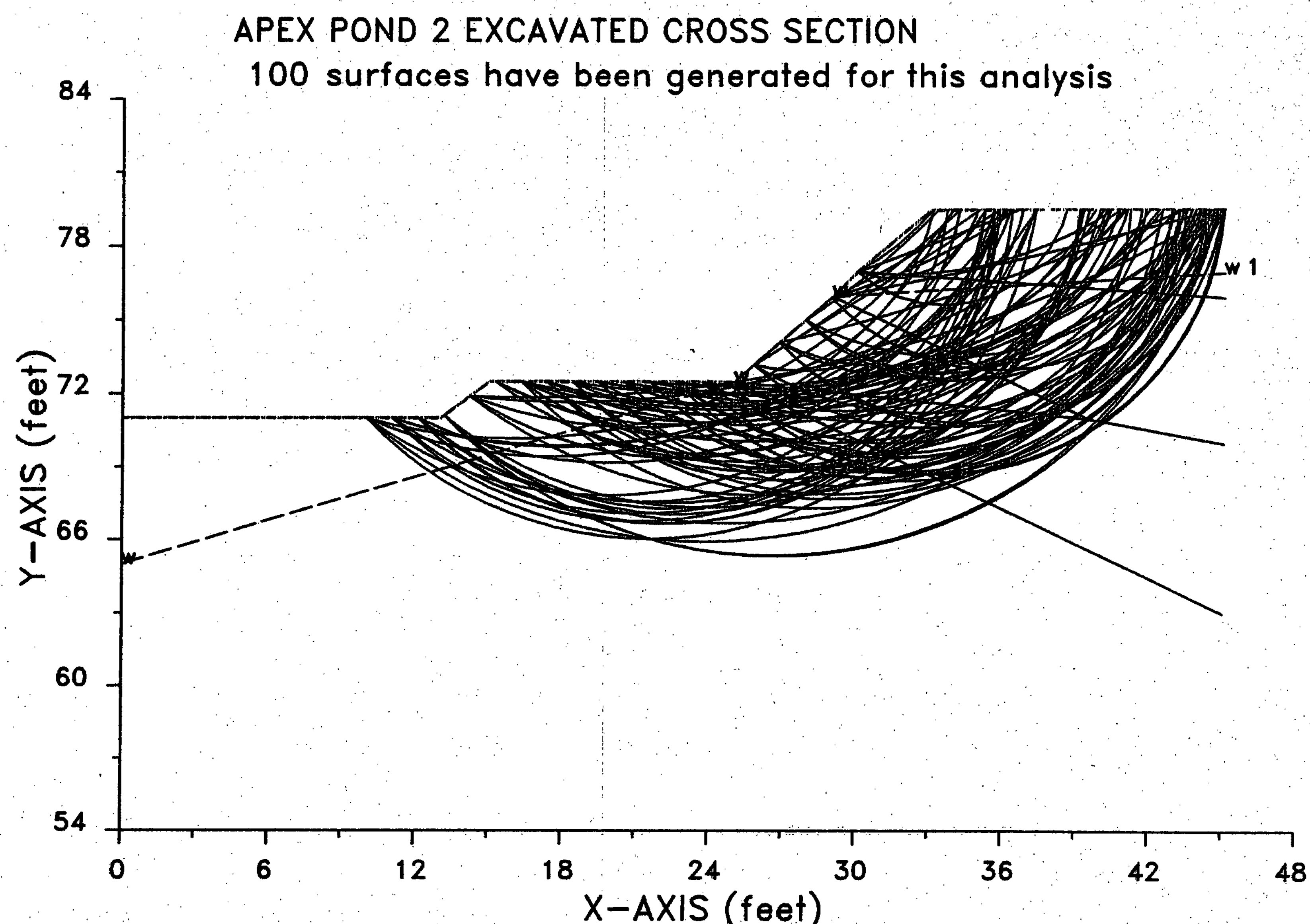
EXC 8-15-03 20:00



EXC 8-15-03 20:00



EXC 8-15-03 20:00



XSTABL File: EXC 8-15-03 20:00

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*****************************************
*              X S T A B L              *
*                                       *
*       Slope Stability Analysis        *
*              using the                *
*           Method of Slices            *
*                                       *
*        Copyright (C) 1992 - 99        *
*   Interactive Software Designs, Inc.  *
*       Moscow, ID 83843, U.S.A.        *
*                                       *
*          All Rights Reserved          *
*                                       *
* Ver. 5.204                96 - 1773   *
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Problem Description : APEX POND 2 EXCAVATED CROSS SECTION

SEGMENT BOUNDARY COORDINATES

----

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	71.0	13.0	71.0	6
2	13.0	71.0	15.0	72.5	6
3	15.0	72.5	25.0	72.5	6
4	25.0	72.5	29.0	76.0	6
5	29.0	76.0	30.0	77.0	5
6	30.0	77.0	33.0	79.5	4
7	33.0	79.5	45.0	79.6	4

5 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	30.0	77.0	45.0	76.0	5
2	29.0	76.0	39.5	71.0	6
3	25.0	72.5	39.5	71.0	7
4	39.5	71.0	45.0	70.0	7
5	25.0	72.5	45.0	63.0	6

ISOTROPIC Soil Parameters

----

7 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	135.0	.0	40.00	.000	.0	1
2	125.0	135.0	100.0	33.00	.000	.0	1
3	90.0	100.0	290.0	25.00	.000	.0	1
4	115.0	125.0	50.0	38.00	.000	.0	1
5	65.0	68.0	200.0	20.00	.000	.0	1
6	120.0	130.0	50.0	38.00	.000	.0	1
7	90.0	100.0	50.0	20.00	.000	.0	1

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 4 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	.00	65.00
2	25.00	72.50
3	29.00	76.00
4	45.00	77.00

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

100 trial surfaces will be generated and analyzed.

5 Surfaces initiate from each of 20 points equally spaced along the ground surface between x = 10.0 ft
and x = 30.0 ft

Each surface terminates between x = 33.0 ft
and x = 45.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = 65.0 ft

```
* * * * *  DEFAULT SEGMENT LENGTH SELECTED BY XSTABL  * * * * *

   1.0 ft line segments define each trial failure surface.


---------------------
ANGULAR RESTRICTIONS
---------------------

  The first segment of each failure surface will be inclined
  within the angular range defined by :

          Lower angular limit :=   -45.0 degrees
          Upper angular limit :=  (slope angle - 5.0) degrees


************************************************************************
   --  WARNING  --  WARNING  --  WARNING  --  WARNING  --  (# 48)
************************************************************************
Negative effective stresses were calculated at the base of a slice.
This warning is usually reported for cases where slices have low self
weight and a relatively high "c" shear strength parameter.  In such
cases, this effect can only be eliminated by reducing the "c" value.
************************************************************************

    ------------------------------------------------------------
    USER SELECTED option for unrestricted values of strength
    ------------------------------------------------------------


    Factors of safety have been calculated by the :

    * * * * *   SIMPLIFIED BISHOP METHOD   * * * * *


      The most critical circular failure surface
      is specified by 17 coordinate points
```

Point No.	x-surf (ft)	y-surf (ft)
1	23.68	72.50
2	24.67	72.32
3	25.66	72.23
4	26.66	72.23
5	27.66	72.33
6	28.64	72.52
7	29.60	72.80
8	30.53	73.17
9	31.42	73.63

10	32.26	74.16
11	33.05	74.78
12	33.78	75.46
13	34.44	76.21
14	35.03	77.02
15	35.54	77.88
16	35.97	78.78
17	36.24	79.53

**** Simplified BISHOP FOS = 1.638 ****

The following is a summary of the TEN most critical surfaces

Problem Description : APEX POND 2 EXCAVATED CROSS SECTION

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	1.638	26.12	82.89	10.67	23.68	36.24	2.917E+04
2.	1.664	27.36	81.83	9.69	24.74	36.76	2.849E+04
3.	1.834	29.46	81.23	9.92	24.74	39.23	3.851E+04
4.	1.841	24.70	80.50	9.02	20.53	33.65	2.312E+04
5.	1.851	27.70	81.17	8.21	25.79	35.73	1.993E+04
6.	1.871	28.61	83.84	12.82	22.63	40.69	6.056E+04
7.	1.890	24.26	81.38	9.02	22.63	33.09	1.489E+04
8.	1.912	24.05	83.56	12.41	18.42	35.77	4.482E+04
9.	1.970	24.46	90.67	19.14	18.42	40.04	8.756E+04
10.	2.009	24.85	92.90	20.86	20.53	40.88	9.040E+04

* * * END OF FILE * * *

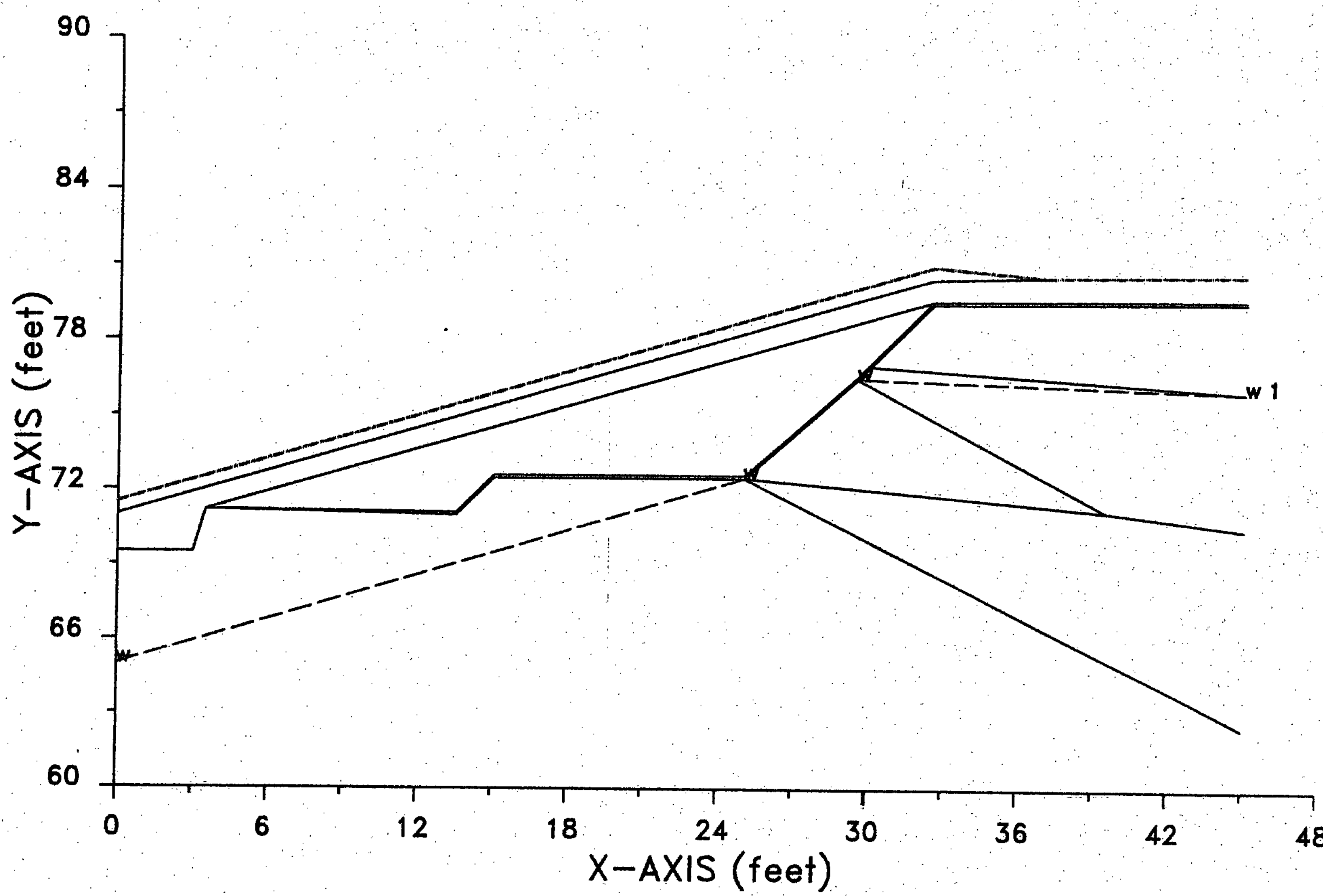
XSTABL Output

Reclaimed Section

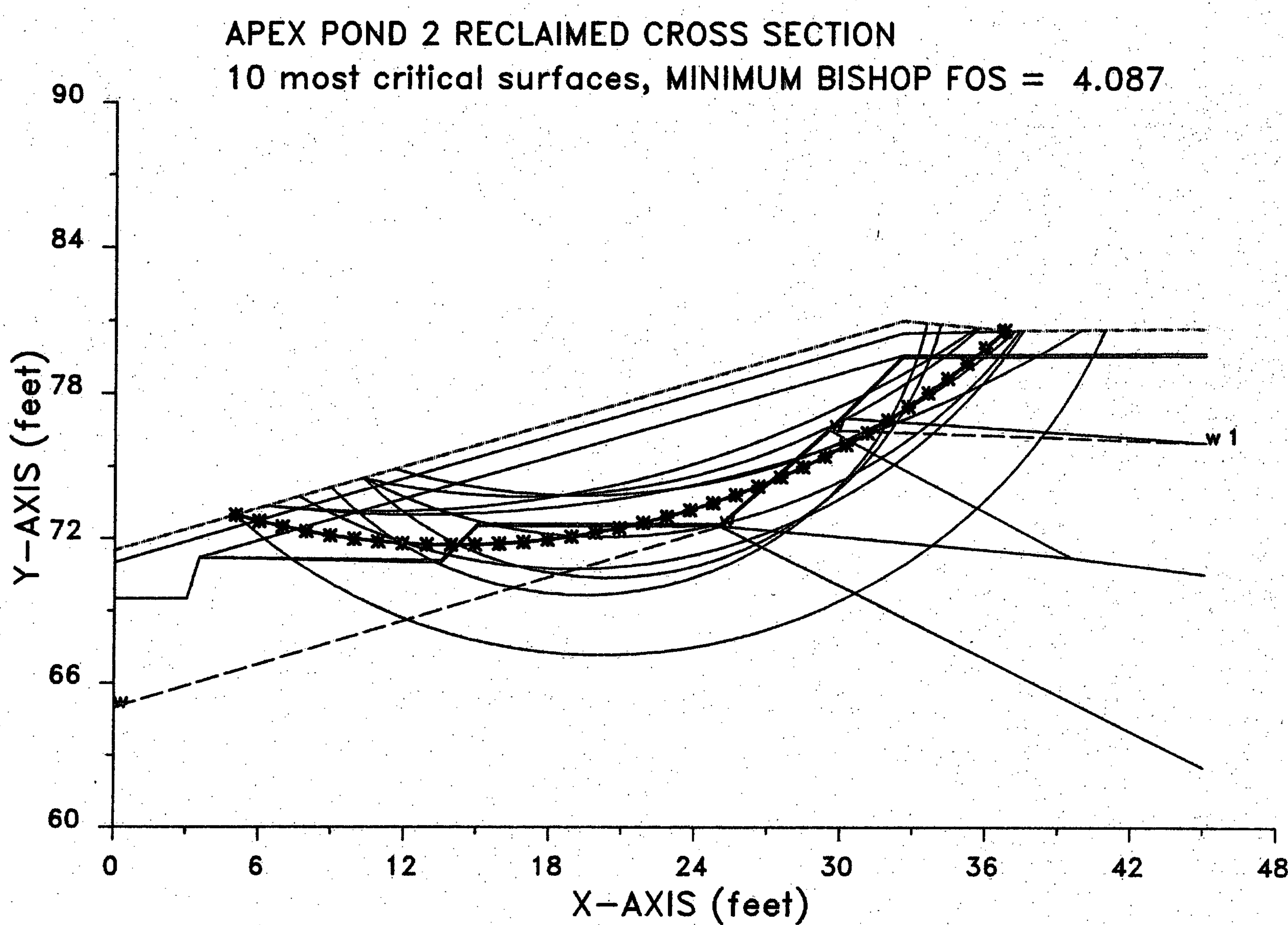
Circular Failure Surfaces

RECL 8-18-03 18:34

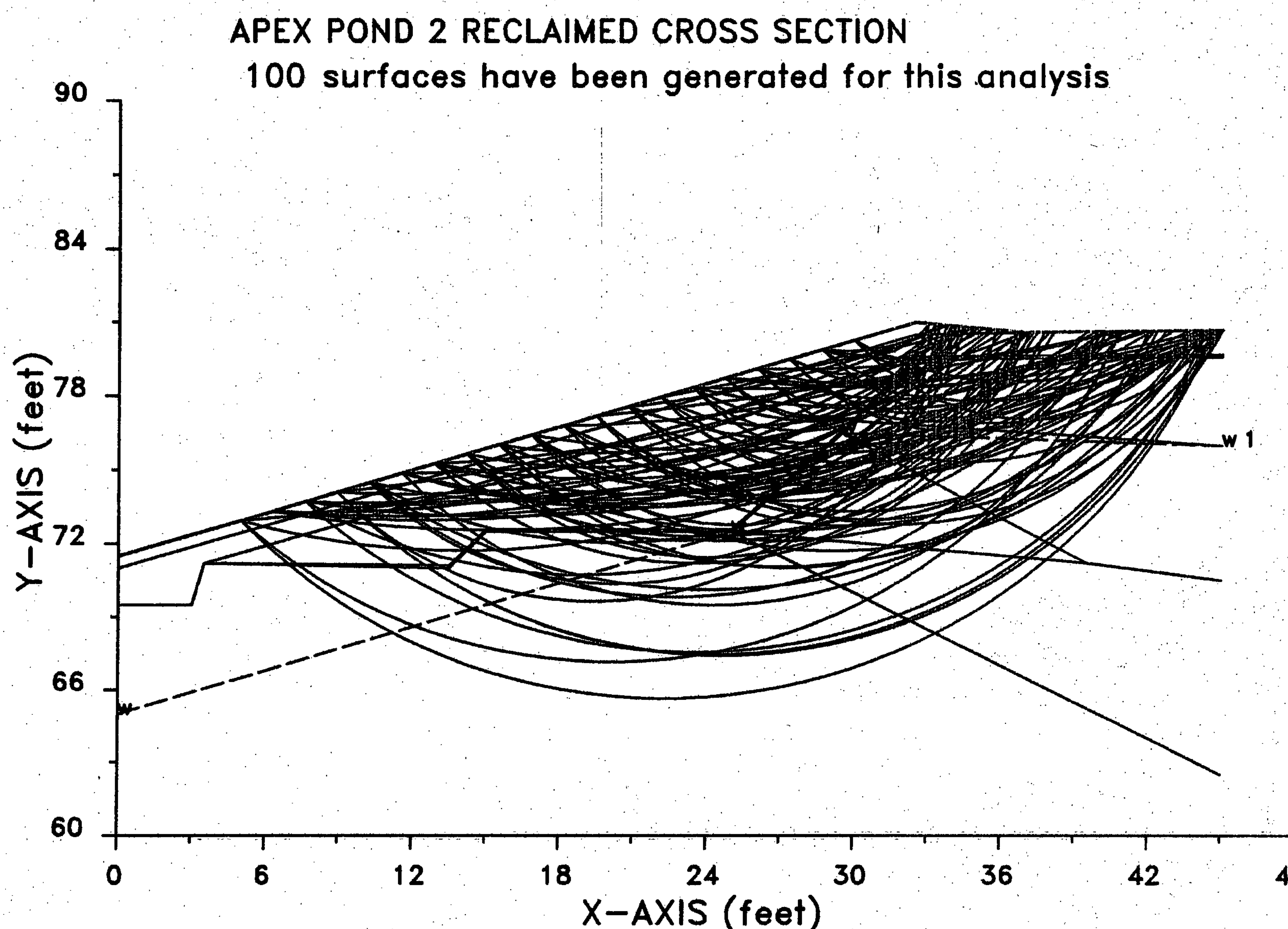
APEX POND 2 RECLAIMED CROSS SECTION



RECL 8-18-03 18:34



RECL 8-18-03 18:34



XSTABL File: RECL 8-18-03 18:34

```
******************************************
*              X S T A B L               *
*                                        *
*       Slope Stability Analysis         *
*              using the                 *
*          Method of Slices              *
*                                        *
*        Copyright (C) 1992 - 99         *
*   Interactive Software Designs, Inc.   *
*       Moscow, ID 83843, U.S.A.         *
*                                        *
*          All Rights Reserved           *
*                                        *
*  Ver. 5.204                96 - 1773   *
******************************************
```

Problem Description : APEX POND 2 RECLAIMED CROSS SECTION

SEGMENT BOUNDARY COORDINATES
----

3 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	71.5	32.5	81.0	1
2	32.5	81.0	37.0	80.6	1
3	37.0	80.6	45.0	80.7	2

24 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	71.0	32.5	80.5	2
2	32.5	80.5	37.0	80.6	2
3	.0	69.5	3.0	69.5	6
4	3.0	69.5	3.5	71.2	6
5	3.5	71.2	32.5	79.6	8
6	32.5	79.6	45.0	79.7	3
7	3.5	71.2	13.5	71.1	3
8	13.5	71.1	15.0	72.6	3
9	15.0	72.6	25.0	72.6	3
10	25.0	72.6	29.5	76.6	3
11	29.5	76.6	30.0	77.1	3
12	30.0	77.1	32.5	79.6	3
13	3.5	71.2	13.5	71.0	6
14	13.5	71.0	15.0	72.5	6
15	15.0	72.5	25.0	72.5	6
16	25.0	72.5	29.5	76.5	6
17	29.5	76.5	30.0	77.0	5
18	30.0	77.0	32.5	79.5	4
19	32.5	79.5	45.0	79.6	4

20	30.0	77.0	45.0	76.0	5
21	29.5	76.5	39.5	71.2	6
22	39.5	71.2	45.0	70.5	7
23	25.0	72.5	39.5	71.2	7
24	25.0	72.5	45.0	62.5	6

ISOTROPIC Soil Parameters
----

8 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	135.0	.0	40.00	.000	.0	1
2	125.0	135.0	100.0	33.00	.000	.0	1
3	90.0	100.0	290.0	25.00	.000	.0	1
4	115.0	125.0	50.0	38.00	.000	.0	1
5	65.0	68.0	200.0	20.00	.000	.0	1
6	120.0	130.0	50.0	38.00	.000	.0	1
7	90.0	100.0	50.0	20.00	.000	.0	1
8	120.0	130.0	200.0	30.00	.000	.0	1

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 4 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	.00	65.00
2	25.00	72.50
3	29.50	76.50
4	45.00	76.00

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

100 trial surfaces will be generated and analyzed.

5 Surfaces initiate from each of 20 points equally spaced along the ground surface between x = 5.0 ft
and x = 30.0 ft

Each surface terminates between x = 33.0 ft

```
                              and    x =     45.0 ft

    Unless further limitations were imposed, the minimum elevation
    at which a surface extends is  y =     65.0 ft


    * * * * *  DEFAULT SEGMENT LENGTH SELECTED BY XSTABL  * * * * *

        1.0 ft line segments define each trial failure surface.


    --------------------
    ANGULAR RESTRICTIONS
    --------------------

      The first segment of each failure surface will be inclined
      within the angular range defined by :

              Lower angular limit :=   -45.0 degrees
              Upper angular limit :=  (slope angle - 5.0) degrees


************************************************************************
    --  WARNING  --  WARNING  --  WARNING  --  WARNING  --  (# 48)
************************************************************************
Negative effective stresses were calculated at the base of a slice.
This warning is usually reported for cases where slices have low self
weight and a relatively high "c" shear strength parameter.  In such
cases, this effect can only be eliminated by reducing the "c" value.
************************************************************************

    -----------------------------------------------------------
    USER SELECTED option for unrestricted values of strength
    -----------------------------------------------------------


    ************************************************************
    **     Factor of safety calculation for surface #    86    **
    **     failed to converge within FIFTY iterations          **
    **                                                         **
    **    The last calculated value of the FOS was  23.2102    **
    **    This will be ignored for final summary of results    **
    ************************************************************


Circular surface (FOS= 23.2102) is defined by: xcenter =     32.98
ycenter =     84.49   Init. Pt. =     27.37   Seg. Length =   1.00
-------------------------------------------------------------------


    ************************************************************
    **     Factor of safety calculation for surface #    89    **
    **     failed to converge within FIFTY iterations          **
    **                                                         **
    **    The last calculated value of the FOS was  31.3215    **
    **    This will be ignored for final summary of results    **
    ************************************************************
```

```
Circular surface (FOS= 31.3215) is defined by: xcenter =     35.05
ycenter =     96.14   Init. Pt. =     27.37   Seg. Length =   1.00
-------------------------------------------------------------------


    *************************************************************
    **     Factor of safety calculation for surface #    90    **
    **     failed to converge within FIFTY iterations          **
    **                                                         **
    **    The last calculated value of the FOS was  30.5756    **
    **    This will be ignored for final summary of results    **
    *************************************************************


Circular surface (FOS= 30.5756) is defined by: xcenter =     34.29
ycenter =     86.16   Init. Pt. =     27.37   Seg. Length =   1.00
-------------------------------------------------------------------


    *************************************************************
    **     Factor of safety calculation for surface #    91    **
    **     failed to converge within FIFTY iterations          **
    **                                                         **
    **    The last calculated value of the FOS was  28.1857    **
    **    This will be ignored for final summary of results    **
    *************************************************************


Circular surface (FOS= 28.1857) is defined by: xcenter =     32.95
ycenter =     85.04   Init. Pt. =     28.68   Seg. Length =   1.00
-------------------------------------------------------------------


    *************************************************************
    **     Factor of safety calculation for surface #    92    **
    **     failed to converge within FIFTY iterations          **
    **                                                         **
    **    The last calculated value of the FOS was  92.1059    **
    **    This will be ignored for final summary of results    **
    *************************************************************


Circular surface (FOS= 92.1059) is defined by: xcenter =     35.80
ycenter =     86.91   Init. Pt. =     28.68   Seg. Length =   1.00
-------------------------------------------------------------------


    *************************************************************
    **     Factor of safety calculation for surface #    93    **
    **     failed to converge within FIFTY iterations          **
    **                                                         **
    **    The last calculated value of the FOS was  39.7618    **
    **    This will be ignored for final summary of results    **
    *************************************************************


Circular surface (FOS= 39.7618) is defined by: xcenter =     33.10
ycenter =    102.25   Init. Pt. =     28.68   Seg. Length =   1.00
-------------------------------------------------------------------
```

```
*******************************************************************
**      Factor of safety calculation for surface #    97      **
**      failed to converge within FIFTY iterations             **
**                                                             **
**    The last calculated value of the FOS was-215.3285       **
**    This will be ignored for final summary of results       **
*******************************************************************
```

```
Circular surface (FOS=********) is defined by: xcenter =     37.24
ycenter =      86.85   Init. Pt. =      30.00   Seg. Length =   1.00
-------------------------------------------------------------------------
```

```
*******************************************************************
**      Factor of safety calculation for surface #    98      **
**      failed to converge within FIFTY iterations             **
**                                                             **
**    The last calculated value of the FOS was-331.1221       **
**    This will be ignored for final summary of results       **
*******************************************************************
```

```
Circular surface (FOS=********) is defined by: xcenter =     36.43
ycenter =      91.65   Init. Pt. =      30.00   Seg. Length =   1.00
-------------------------------------------------------------------------
```

Factors of safety have been calculated by the :

* * * * *   SIMPLIFIED BISHOP METHOD   * * * * *

The most critical circular failure surface
is specified by 36 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	5.00	72.96
2	5.97	72.71
3	6.94	72.48
4	7.92	72.28
5	8.91	72.11
6	9.90	71.98
7	10.89	71.87
8	11.89	71.79
9	12.89	71.74
10	13.89	71.72
11	14.89	71.73
12	15.89	71.77
13	16.88	71.85
14	17.88	71.95
15	18.87	72.08
16	19.86	72.24
17	20.84	72.43
18	21.81	72.65
19	22.78	72.90
20	23.74	73.17

21	24.70	73.48
22	25.64	73.81
23	26.57	74.18
24	27.49	74.57
25	28.40	74.98
26	29.29	75.43
27	30.18	75.90
28	31.04	76.40
29	31.90	76.92
30	32.73	77.47
31	33.55	78.04
32	34.35	78.64
33	35.14	79.26
34	35.90	79.91
35	36.65	80.58
36	36.70	80.63

**** Simplified BISHOP FOS = 4.087 ****

```
**********************************************************************
**                                                                  **
**  Out of the    100 surfaces generated and analyzed by XSTABL,   **
**        8 surfaces were found to have MISLEADING FOS values.     **
**                                                                  **
**********************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : APEX POND 2 RECLAIMED CROSS SECTION

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	4.087	14.01	105.08	33.36	5.00	36.70	4.483E+05
2.	4.284	18.85	93.18	22.46	7.63	37.45	3.474E+05
3.	4.510	20.20	93.44	21.38	10.26	37.30	2.731E+05
4.	4.580	16.86	102.46	28.72	10.26	35.63	2.663E+05
5.	4.636	10.82	116.99	43.87	6.32	35.52	4.385E+05
6.	4.680	12.50	125.55	52.57	6.32	39.82	6.436E+05
7.	4.695	19.21	100.64	26.86	11.58	37.09	2.626E+05
8.	4.727	20.12	89.77	22.61	5.00	40.81	5.505E+05
9.	4.752	19.39	84.06	14.43	8.95	33.47	2.231E+05
10.	4.757	20.30	84.60	14.24	10.26	34.04	2.013E+05

* * * END OF FILE * * *

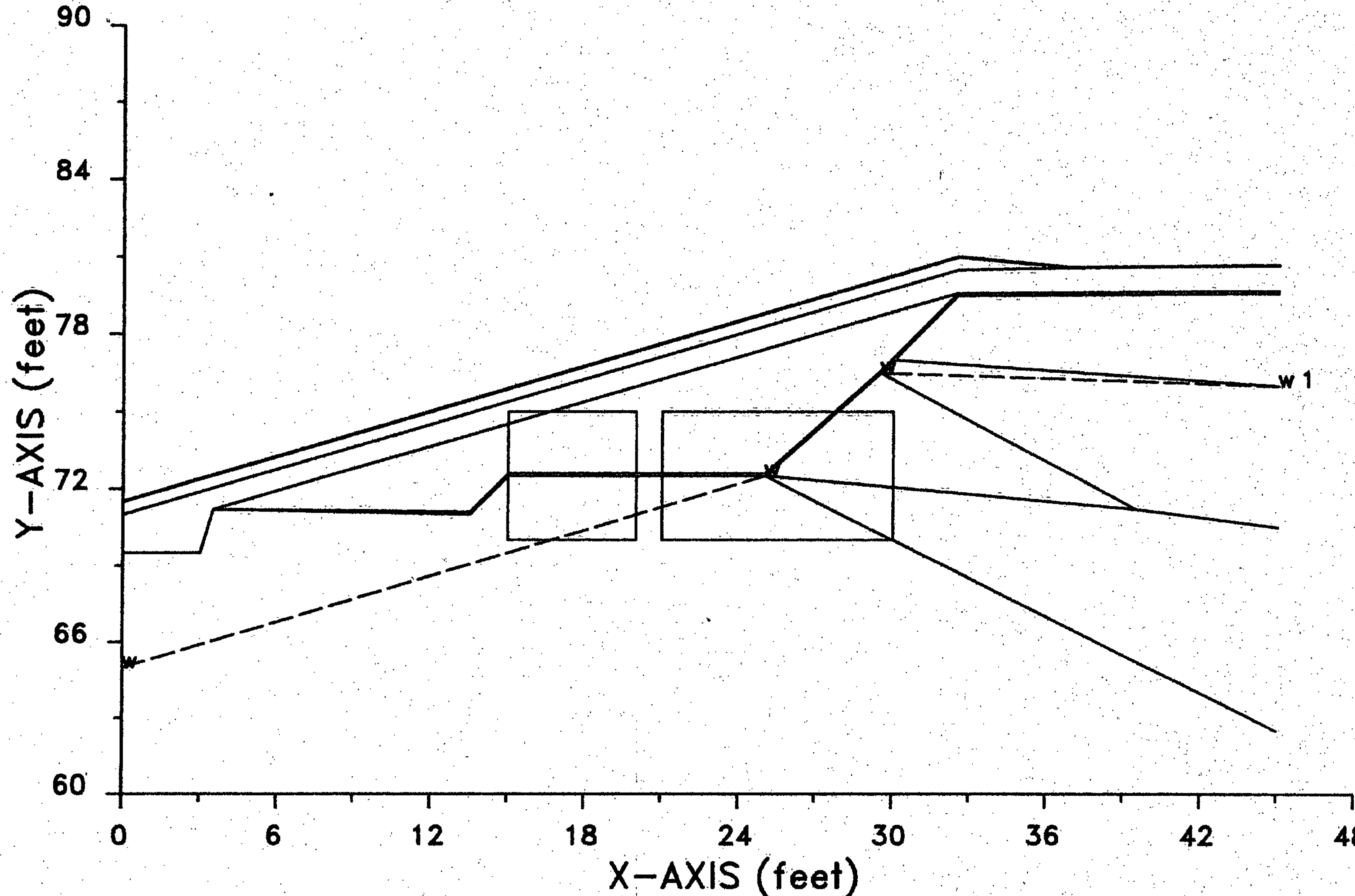
XSTABL Output

Reclaimed Section

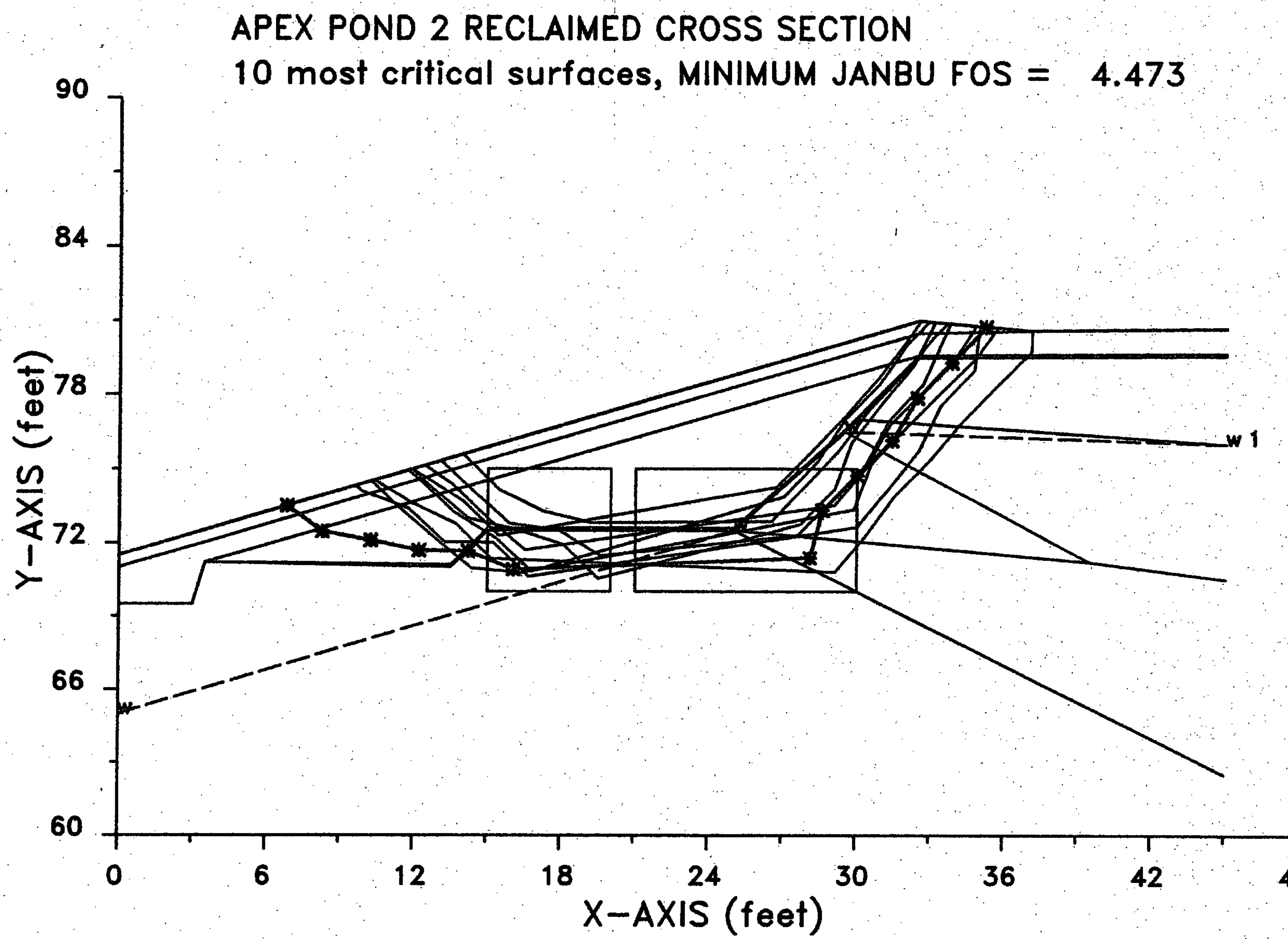
Block Failure Surfaces

RECLBLCK 8-18-03 18:36

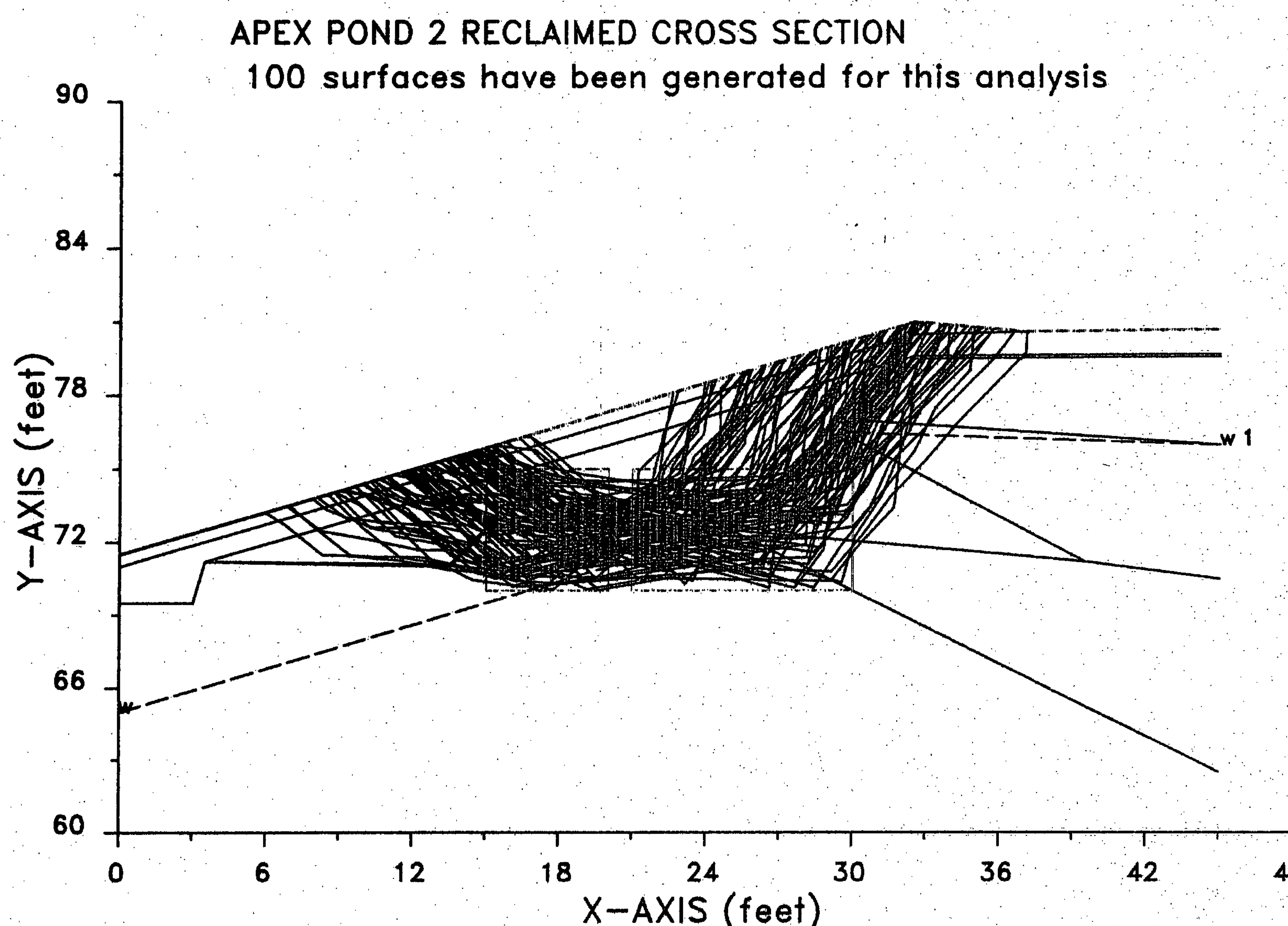
APEX POND 2 RECLAIMED CROSS SECTION



RECLBLCK 8-18-03 18:36



RECLBLCK 8-18-03 18:06



XSTABL File: RECLBLCK 8-18-03 18:36

```
******************************************
*              X S T A B L               *
*                                        *
*        Slope Stability Analysis        *
*               using the                *
*            Method of Slices            *
*                                        *
*         Copyright (C) 1992 - 99        *
*     Interactive Software Designs, Inc. *
*       Moscow, ID 83843, U.S.A.         *
*                                        *
*          All Rights Reserved           *
*                                        *
*  Ver. 5.204               96 - 1773    *
******************************************
```

Problem Description : APEX POND 2 RECLAIMED CROSS SECTION

SEGMENT BOUNDARY COORDINATES

3 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	71.5	32.5	81.0	1
2	32.5	81.0	37.0	80.6	1
3	37.0	80.6	45.0	80.7	2

24 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	71.0	32.5	80.5	2
2	32.5	80.5	37.0	80.6	2
3	.0	69.5	3.0	69.5	6
4	3.0	69.5	3.5	71.2	6
5	3.5	71.2	32.5	79.6	8
6	32.5	79.6	45.0	79.7	3
7	3.5	71.2	13.5	71.1	3
8	13.5	71.1	15.0	72.6	3
9	15.0	72.6	25.0	72.6	3
10	25.0	72.6	29.5	76.6	3
11	29.5	76.6	30.0	77.1	3
12	30.0	77.1	32.5	79.6	3
13	3.5	71.2	13.5	71.0	6
14	13.5	71.0	15.0	72.5	6
15	15.0	72.5	25.0	72.5	6
16	25.0	72.5	29.5	76.5	6
17	29.5	76.5	30.0	77.0	5
18	30.0	77.0	32.5	79.5	4
19	32.5	79.5	45.0	79.6	4
20	30.0	77.0	45.0	76.0	5
21	29.5	76.5	39.5	71.2	6
22	39.5	71.2	45.0	70.5	7
23	25.0	72.5	39.5	71.2	7
24	25.0	72.5	45.0	62.5	6

ISOTROPIC Soil Parameters

8 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	135.0	.0	40.00	.000	.0	1
2	125.0	135.0	100.0	33.00	.000	.0	1
3	90.0	100.0	290.0	25.00	.000	.0	1
4	115.0	125.0	50.0	38.00	.000	.0	1
5	65.0	68.0	200.0	20.00	.000	.0	1
6	120.0	130.0	50.0	38.00	.000	.0	1
7	90.0	100.0	50.0	20.00	.000	.0	1
8	120.0	130.0	200.0	30.00	.000	.0	1

1 Water surface(s) have been specified
Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 4 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	.00	65.00
2	25.00	72.50
3	29.50	76.50
4	45.00	76.00

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

100 trial surfaces will be generated and analyzed.
2 boxes specified for generation of central block base

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *
Length of line segments for active and passive portions of sliding block is 2.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	15.0	72.5	20.0	72.5	5.0
2	21.0	72.5	30.0	72.5	5.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	6.84	73.50
2	8.28	72.47
3	10.25	72.11
4	12.20	71.69
5	14.20	71.66
6	16.05	70.90
7	28.10	71.38

8	28.60	73.32
9	30.01	74.74
10	31.42	76.15
11	32.44	77.87
12	33.84	79.31
13	35.22	80.76
14	35.22	80.76

** Corrected JANBU FOS = 4.473 ** (Fo factor = 1.081)

Failure surface No. 2 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	10.27	74.50
2	11.26	73.52
3	12.79	72.23
4	14.34	70.97
5	16.33	70.76
6	29.87	73.33
7	30.57	75.21
8	31.96	76.64
9	33.37	78.06
10	34.79	79.47
11	35.68	80.72

** Corrected JANBU FOS = 4.619 ** (Fo factor = 1.076)

Failure surface No. 3 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	13.10	75.33
2	14.40	74.11
3	15.89	72.78
4	17.87	72.52
5	19.59	71.48
6	27.59	72.31
7	28.99	73.74
8	30.35	75.21
9	31.29	76.97
10	32.67	78.43
11	33.48	80.25
12	33.77	80.89

** Corrected JANBU FOS = 4.626 ** (Fo factor = 1.088)

Failure surface No. 4 specified by 10 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	12.44	75.14
2	13.55	74.38
3	15.00	73.00
4	16.52	71.71
5	29.07	73.51
6	30.36	75.04
7	31.32	76.79
8	32.74	78.21
9	34.10	79.67
10	34.80	80.80

** Corrected JANBU FOS = 4.729 ** (Fo factor = 1.081)

Failure surface No. 5 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	10.38	74.53
2	11.91	73.60
3	13.72	72.75
4	15.15	71.35
5	29.11	70.79
6	30.39	72.33
7	31.57	73.95
8	32.98	75.37
9	34.26	76.91
10	35.66	78.33
11	37.05	79.77
12	37.09	80.60

** Corrected JANBU FOS = 4.764 ** (Fo factor = 1.086)

Failure surface No. 6 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	14.01	75.60
2	14.05	75.56
3	15.47	74.15
4	17.27	73.27
5	19.21	72.81
6	26.54	72.87
7	27.91	74.33
8	29.28	75.79
9	30.47	77.40
10	31.86	78.83
11	33.13	80.38
12	33.65	80.90

** Corrected JANBU FOS = 4.782 ** (Fo factor = 1.086)

Failure surface No. 7 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	9.63	74.31
2	9.89	74.08
3	11.76	73.39
4	13.24	72.04
5	15.24	72.02
6	16.67	70.62
7	29.98	72.64
8	31.27	74.17
9	32.51	75.74
10	33.38	77.54
11	34.75	78.99
12	34.96	80.78

** Corrected JANBU FOS = 4.798 ** (Fo factor = 1.082)

Failure surface No. 8 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	11.91	74.98
2	12.68	74.26
3	14.22	72.99
4	16.17	72.54
5	18.07	71.93

6	19.50	70.53
7	27.69	72.75
8	29.08	74.19
9	29.77	76.07
10	31.00	77.64
11	32.28	79.18
12	33.14	80.94

** Corrected JANBU FOS = 4.842 ** (Fo factor = 1.086)

Failure surface No. 9 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	11.75	74.93
2	12.17	74.61
3	13.62	73.24
4	15.33	72.20
5	16.80	70.83
6	27.03	73.86
7	28.40	75.32
8	29.49	77.00
9	30.89	78.42
10	32.03	80.07
11	32.91	80.96

** Corrected JANBU FOS = 4.911 ** (Fo factor = 1.080)

Failure surface No.10 specified by 10 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	11.89	74.98
2	12.33	74.75
3	14.01	73.67
4	15.46	72.29
5	26.69	74.25
6	28.11	75.67
7	29.48	77.12
8	30.81	78.62
9	32.02	80.21
10	32.56	80.99

** Corrected JANBU FOS = 4.926 ** (Fo factor = 1.077)

****
** **
** Out of the 100 surfaces generated and analyzed by XSTABL, **
** 38 surfaces were found to have MISLEADING FOS values. **
** **
****

The following is a summary of the TEN most critical surfaces

Problem Description : APEX POND 2 RECLAIMED CROSS SECTION

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	4.473	1.081	6.84	35.22	1.516E+04
2.	4.619	1.076	10.27	35.68	1.397E+04
3.	4.626	1.088	13.10	33.77	1.145E+04

4.	4.729	1.081	12.44	34.80	1.169E+04
5.	4.764	1.086	10.38	37.09	1.517E+04
6.	4.782	1.086	14.01	33.65	9.845E+03
7.	4.798	1.082	9.63	34.96	1.432E+04
8.	4.842	1.086	11.91	33.14	1.232E+04
9.	4.911	1.080	11.75	32.91	1.144E+04
10.	4.926	1.077	11.89	32.56	9.845E+03

*** END OF FILE ***

Appendix F

Runoff Evaluation and Erosion Protection Sizing Analyses

Appendix F – Runoff Evaluation and Erosion Protection Sizing Analysis

This appendix is separated into three sections containing results, data, and calculations for the:

- Runoff Evaluation
- Diversion Channel Flow and Erosional Stability Analyses
- Pond 2 Outslope Flow and Erosional Stability Analyses

for the selected Final Closure Plan alternative for Pond 2 at Hecla Mining Company's Apex Site near St. George, Utah.

Runoff Evaluation

Storm water runoff analyses were conducted on the selected cover system alternative for Pond 2 (the impoundment) at Hecla Mining Company's Apex Site, and on all contributory areas surrounding the impoundment.

Method of Analysis

Peak flows from the reclaimed impoundment surface and all surrounding areas upgradient of the site were estimated using the HEC-HMS computer program which was developed by the U.S. Army Corps of Engineers (USACE 2002). Factors which determine the peak flow rate from a basin are rainfall amount, distribution of precipitation, and runoff parameters of the basin (area, soil type, geometry, and slope).

The design event selected for the Apex Site was the 6-hour, 25-year event as it produced for more intense runoff (larger flow rates) than the 24-hour, 25-year event. Site specific precipitation amounts for both the 6-hour and 24-hour duration events with recurrence intervals of 25 years were determined from National Oceanic and Atmospheric Administration maps (WRCC 2003). Storm depths from the 6-hour and 24-hour events respectively were determined to be 1.9 and 2.4 inches. The rainfall event was distributed (in time) using the Soil Conservation Service (SCS) Type II distribution. Data and calculations showing selected soil types, rainfall distribution, and peak flows are included in this appendix after the References section.

Description of Basins

Runoff contributory to the main diversion channel (east side of the impoundment) was determined to derive from areas south of the impoundment and from the eastern half of the reclaimed impoundment surface. Contributory areas are outlined on Figure 1. An additional basin, consisting of a 50-foot wide strip on top of the reclaimed impoundment surface was used to assess erosional stability of the cover system outslope during the design storm event.

Soils in the vicinity of the Apex Site consist primarily of silts and clays, therefore, they were assumed to be in the Hydrologic Soil Group "C" which represents soils with moderately high runoff potential. The curve number parameter (83) was selected as the most suitable for this site from SCS values presented in Schwab (Schwab 1981). Basin parameters are listed in Table 1 below. Data and calculations, including a schematic of the basins showing flow directions and contributory areas are included after the References section.

Table 1
Summary of Basin Parameters

Basin	Area (ac)	Area (sq mi)	SCS Curve Number	Hydraulic Length (ft)	Surface Slope (%)	Lag Time (min)
East 1	6.2	0.0097	83	1,300	12.2	6.1
East 2	9.7	0.0152	83	1,250	2.9	12.1
East 3	10.8	0.0169	83	1,100	13.2	5.1
East 4	5.6	0.0088	83	500	6.0	4.0
½ Pond 2	5.7	0.0045	83	280	1	6.2
50' strip	0.32	0.0005	83	280	1	6

Routing Parameters

Flood routing was used in the analysis of the total watershed area. The Muskingham routing method was utilized to include time effects (delay of peak flow) when routing flows from one location to another in the watershed. This method requires a channel constant x and a time constant K. Routing parameters used are summarized in Table 2 below.

Table 2
Muskingham Routing Parameters

Reach	Velocity (ft/s)	Length (ft)	K (hrs)	x
East-1 to East-2	3.0	950	0.088	0.319
East-2 to East-4	3.0	500	0.046	0.319
East-3 to East-4	5.0	400	0.022	0.373

Selection of Design Storm Duration

A sensitivity analysis was performed to determine the appropriate duration of the 25-year storm event. A one-acre watershed was defined and subjected to both the 6-hour and 24-hour duration storm events. Peak runoff from the 6-hour event was 1.07 cubic feet per second (cfs) and peak runoff from the 24-hour event was 0.3 cfs. The 6-hour event had a larger peak runoff primarily due to the higher intensity of precipitation during the 6-hour event. Conservatively the higher peak runoff value (6-hour storm) was utilized for all further runoff and erosion protection sizing calculations.

Results

Peak flows from the 6-hour, 25-year, 1.9-inch storm event were calculated for the defined watershed and are listed in Table 3 below.

Table 3
List of Peak Flows (6-hour, 25-year event)

Location	Peak Flow (cfs)
East-1	5.4
East-1 routed flow	5.2
East-2	6.8
East-1 and East-2 combined	12.0
Combined E-1 and E-2 routed to Junction-2	11.7
East-3	9.9
East-3 routed to Junction-2	9.9
½ of Pond 2 Surface	2.5
Junction-2	22.0
East-4	5.4
Junction-3	26.6
50-foot wide strip of Pond 2 surface	0.3

Diversion Channel Flow and Erosional Stability Analyses

Analysis of Flow Conditions

Flow conditions at selected locations along the diversion channel were assessed to determine if there was a requirement for erosion protection along the diversion channel or at the toe of the impoundment outslope. All data, figures, and calculations are included after the References section.

The constructed diversion channel begins at Hecla's southern property line, flows along the east side of the impoundment, and ends near the north side of the impoundment (Figure 9, MEI, 2003b). Channel left slope, right slope, bed slope, and width were determined from the conceptual diversion plan (MEI 2003b). A channel bed slope of 3.65% was calculated based on cross-sections at TP-4 and TP-2 shown in Figure 8 (MEI 2003b).

The peak flow calculated for all contributory drainages of 26.6 cfs was rounded up to 27 cfs. The actual location of this peak flow is near the east-central extent of the impoundment. For conservative evaluation of flow conditions within the diversion, this peak flow was utilized at all locations. A Manning's 'n' value of 0.03 was selected to represent a primarily bare, earthen channel (Schwab 1981). Flow conditions within the diversion channel are summarized in Table 4 below.

Table 4
Summary of Flow Conditions in Diversion Channel

Location	Channel Slope (%)	Depth of Flow (ft)	Velocity (ft/sec)
Cross section @ TP-4	3.65	0.63	4.4
Cross section @ TP-2	3.65	0.67	4.5

Tractive Force Analysis of Flow Velocities

The Temple shear stress method (Temple 1987) was used to evaluate erosion resistance of native soils along the channel bottom. This method uses soil characteristics to find the allowable stress that the soil can undergo and remain stable. Runoff characteristics derived from the 25-year, 6-hour storm were used to find the effective stress that runoff will impart to the soil surface. The effective stress must be less than the allowable soil stress for the channel surface to remain stable. Allowable soil stress was calculated based on limited laboratory test results from site soils sampled at depth (MEI 2003a). Allowable and effective stress calculations are given in the attachment. Results of shear stress analysis presented in

Table 5 below indicate that soils within the diversion should remain stable when subjected to the design storm.

Table 5
Summary of Temple Shear Stress Evaluation

Location	Effective Shear (psf)	Allowable Shear (psf)	Allowable/Effective (ft/sec)
Cross section @ TP-4	0.0663	0.0894	1.35
Cross section @ TP-2	0.0706	0.0894	1.27

Given the uncertainty of using test results from samples intended to characterize potential borrow soils, and the current diversion channel conditions shown in site photos which indicate movement of bedload, it is likely that due to infrequent, large storm events some long-term movement of the diversion channel will occur. Therefore, it is recommended that gravel materials which are utilized to stabilize the impoundment outslope also be entrenched three feet beneath the final surrounding surface elevation to help protect the impoundment outslope from potential, long-term migration of the channel.

Diversion Channel Erosion Protection Analysis

Riprap or rock protection sizing analyses were performed for the entire length of the diversion channel. Two different methods of analysis were compared; the Safety Factors and Corps of Engineer's. The Safety Factors Method is most applicable at the intersection of the impoundment outslope and the diversion channel bottom, as it is applicable for evaluation of rock stability from flows parallel and adjacent to a slope (Abt 1988). The Safety Factors Method requires inputs of flow depth, channel slope, channel side slope, riprap angle of repose, and a trial D_{50} (median riprap size) to calculate the safety factor for a given rock size. For this analysis an angle of repose of 40 degrees was used. Results of the rock sizing calculations are given in Table 6 below.

Table 6
Summary of Diversion Channel Erosion Protection Calculations

Location	Channel Slope (%)	Flow Depth (ft)	Flow Velocity (fps)	Safety Factors Method D_{50} (in)	C.O.E. Method D_{50} (in)
Cross section @ TP-4	3.65	0.63	4.4	3	1
Cross section @ TP-2	3.65	0.67	4.5	3	1

Based on rock sizes presented above, the placement of riprap with a D_{50} of at least three inches is recommended along the east-side toe of the impoundment. The rock should be placed at the toe and extend beneath the final ground surface of the diversion channel to a depth of approximately three feet.

Pond 2 Outslope Flow and Erosional Stability Analyses

To assess flow conditions and erosional stability of any given section of the reclaimed top surface and outslope of the impoundment, the peak flow from a sub-basin consisting of a 50-foot wide strip was calculated. The peak flow determined by the HEC-HMS model from the 25-year, 6-hour storm event is 0.28 cfs. This value was conservatively rounded up to 0.3 cfs. To account for variations and irregularities in the reclaimed impoundment surface due to grading imperfections and potential differential settlement, a conservative concentration factor of 3 was applied to this peak flow. In effect, the peak flow from a 150-foot wide strip was applied to the 50-foot wide strip. The resulting peak flow of 0.9 cfs was conservatively rounded up to 1.0 cfs. This peak flow of 1.0 cfs was analyzed using Manning's formula to determine depth and velocity of flow over the impoundment surface. A Manning's 'n' value of 0.40 was selected to model the roughness and resulting tortuous flow path produced by runoff flowing through the final gravel/soil surface layer. Results of the calculation for flow on the pile surface and outslope are listed in Table 7 below.

Table 7
Results of Flow Analysis by Manning's Formula

Parameter	Top Surface	Outslope
Flow (cfs)	1	1
Mannings 'n'	0.04	0.04
Width (ft)	50	50
Slope (%)	1	28.6
Flow Depth (ft)	0.04	0.02
Flow Velocity (fps)	0.5	1.2

The outslope grade and corresponding flow depth and velocity were input into a rock-sizing calculation spreadsheet. Though the flow depth and velocity are minimal, the outslope gradient is fairly steep

(3.5h:1v). The Safety Factors Method, which is slope-dependant, was stable with a D_{50} of ¾-inch. Analysis by the Corps of Engineer's method, which is velocity-dependant, showed that a factor of safety of greater than 1 was achieved when D_{50} values reached ¼-inch to 1/2-inch. The Corps of Engineer's method also showed that with a D_{50} value of ¾-inch or larger, the factor of safety was less than 1. The Corps of Engineer's Method was therefore determined to be inaccurate for this analysis as it showed that increasing rock size reduced erosional stability.

Based on the Safety Factors method, the use of rock material with a D_{50} of ¾-inch or larger is recommended to ensure a factor of safety greater than 1.

As the previous diversion channel flow analysis indicated the impoundment outslope would be stable with a D_{50} of three inches, this same three inch material could be utilized for both outslope protection and toe protection. Typically, literature recommends the use of a lift thickness that is at least 1.5 times the D_{50}. Experience has shown that this can be difficult depending on the material and experience level of earthmoving personnel. A lift thickness of 2 times the D_{50} (6-inch lift) would facilitate ease of placement for the rock material.

References

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MEI 2003a. Monster Engineering Inc., "Apex Site Potential Borrow Source Materials Investigation." Prepared for Hecla Mining Company, February 3.

MEI 2003b. Monster Engineering Inc., "Apex Site – Pond 2 Conceptual Final Closure Alternatives, Draft Technical Memorandum." Prepared for Hecla Mining Company, March 25.

Schwab 1981. Schwab, G.O., R.K. Frevert, T.W. Edminster, and K.K. Barnes. "Soil and Water Conservation Engineering." John Wiley and Sons, New York, New York.

USACE 2002. U.S. Army Corps of Engineers. Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS), Version 2.2.1, October 24.

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Runoff Evaluation and Erosion Protection Sizing Analyses

Figures, Data, and Calculations

HECLA MINING COMPANY

COEUR D'ALENE, IDAHO 83814

BY DTM	DATE 5/26/03	JOB TITLE APEX Pond 2 Closure	JOB NO.
CHK.	DATE		DIVISION
DWG. NO.		Runoff Calcs	SHEET 4 OF 14

<u>Select Soil Conservation Service (SCS) Curve Number (CN)</u>

Available information on site soils MEI 3/2003 Borrow Source Investigation

Shivwits Dam CL-ML

Hecla TP-1 0-9' CL

→ Soil Group C Moderately High Runoff Potential Comprises shallow soils and soils containing considerable clay and colloids; below average infiltration after pre-saturation

Pasture or Range fair condition AMC II Group C CN = 79

poor condition " " 86

83

Ground cover is brush neither sparse or dense ∴ CN = 83

Storm Duration - Peak Runoff Evaluation

Use 1acre area 0.0016 sq mi

CN = 83

$T_c = 0.0195\ L^{0.77} S^{-.385}$ where T_c = time of concentration (min)

$= 0.0195\ 64^{.77}\ 0.02^{-.385}$ L = max length of flow (m) 64 m

$= 2.2$ min S = watershed gradient (1/1) 2% = .02

25YR 6HR 1.9" peak Q = 1.07 cfs SCS Type II dist see p51

24HR 2.4" peak Q = 0.3 cfs " " " "

∴ utilize 6HR storm duration & SCS Type II distribution for runoff calculations

HECLA MINING COMPANY

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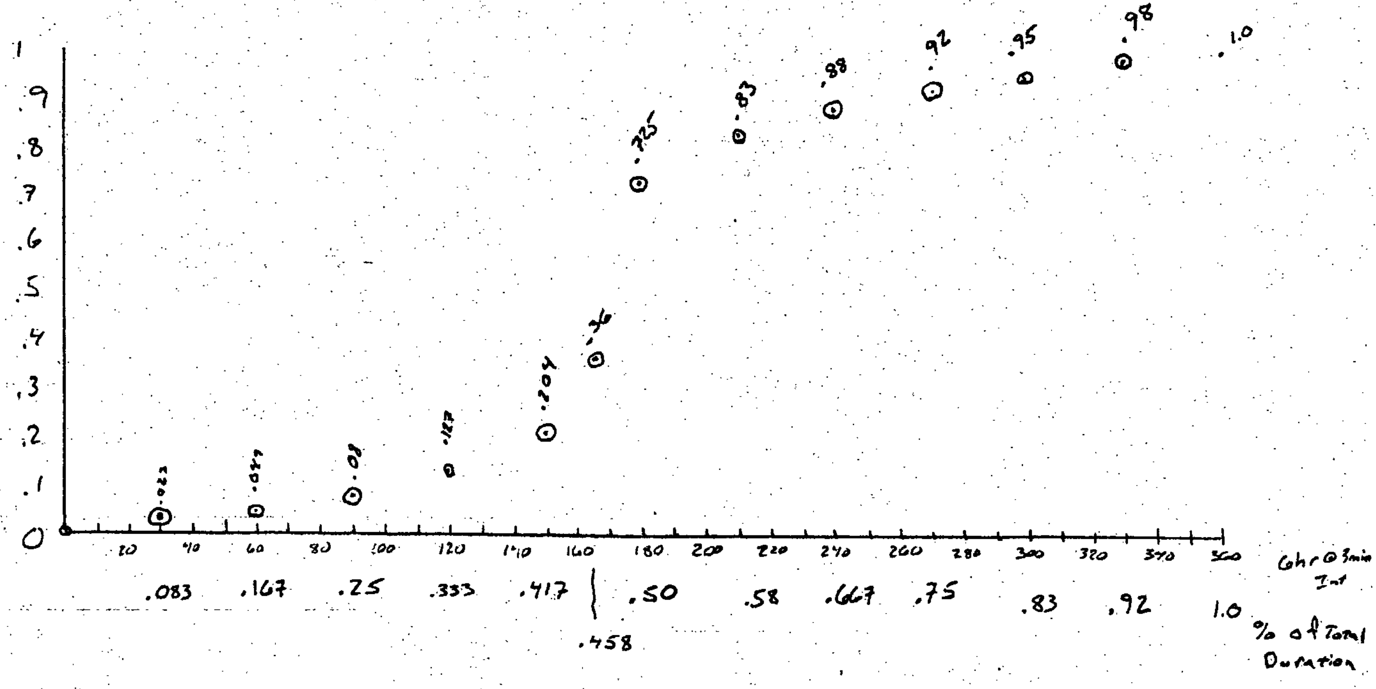
BY DTM	DATE 5/26/03	JOB TITLE APEX Pond 2	JOB NO.
CHK.	DATE		DIVISION
DWG. NO.		Runoff Calcs	SHEET 5 OF 14

SCS Type II Rainfall Distribution



HEC HMS Time of Storm	6HR Storm % of Time	TYPE II ratio	depth(in)	24HR Storm % of total	TYPE II ratio	depth(in)
5min	.0139	.0036	.007	.0035	.001	.002
15min	.0417	.011	.021	.0104	.0028	.007
1hr	.1667	.049	.093	.0417	.0110	0.026
2	.3333	.127	.24	.083	.023	.055
3	0.5	.725	1.38	.125	.035	0.084
6	1.0	1.0	1.9	.25	.080	0.19
12	—			.5	.725	1.74
24	—			1.0	1.0	2.4

25YR 6HR = 1.9" 360min

25YR 24HR = 2.4" 1440min

HMS * Summary of Results

Project : Hecla_APEX Run Name : Run 1

Start of Run : 01Jun03 1200 Basin Model : Basin 1
End of Run : 02Jun03 1200 Met. Model : Met 1
Execution Time : 26May03 1733 Control Specs : Control 1

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	1.0676	01 Jun 03 1630	0.053564	0.002

peak flow from 25YR 6HR 1.9IN Event
w/ SCS TypeII Distribution

HMS * Summary of Results

Project : Hecla_APEX   Run Name : Run 1

Start of Run	: 01Jun03 1200	Basin Model	: Basin 1
End of Run	: 02Jun03 1200	Met. Model	: Met 1
Execution Time	: 26May03 1727	Control Specs	: Control 1

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	0.32412	02 Jun 03 0600	0.083558	0.002

peak flow from 25YR 24HR 2.4IN Event
w/ SCS Type II distribution

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BY DTA	DATE 5/26/03	JOB TITLE APEX Pond 2 Closure	JOB NO.
CHK.	DATE	Runoff Calc	DIVISION
DWG. NO.			SHEET 2 OF 14

Calculate Sub-Basin Areas (from 1"=200' Site Map)

West $(550 ft \times 200) + 400 \times \left(\frac{180+50}{2}\right) = 156{,}000\ ft^2$ = ~~3.6ac~~

Exclude; runoff detained w/in OMG Pond DTA 6/1/03

East 1: $\frac{1}{2}\ 150 \cdot 220 + 270 \cdot 120 + 360 \cdot 190 + 190 \cdot 310 + 260 \cdot 360$

$= 269{,}800\ ft^2 = 6.2ac$

East 2: $320 \cdot 500 + 300 \cdot 450 + 180 \cdot 520 + \frac{1}{2}\ 550 \cdot 120$

$= 421{,}600\ ft^2 = 9.7ac$

East 3: $\frac{1}{2}\ 280 \cdot 770 + 290 \cdot 850 + \frac{1}{2}\ 280 \cdot 830$

$= 470{,}500\ ft^2 = 10.8ac$

East 4: $520 \cdot 290 + 230 \cdot 400 = 242{,}800 = 5.6ac$

Sub-Basin	Area (ac)	HMS Area sq mi
~~West~~	~~3.6~~	.0056
East 1	6.2	.0097
East 2	9.7	.0152
East 3	10.8	.0169
East 4	5.6	.0088
East Sub-total	32.3	
All	35.9	

Storm Intensity evaluation use 1ac .0016

HECLA MINING COMPANY

COEUR D'ALENE, IDAHO 83814

BY DTM	DATE 6/1/03	JOB TITLE APEX POND 2 CLOSURE	JOB NO.
CHK.	DATE		DIVISION
DWG. NO.		Runoff Calcs	SHEET 3 OF 14

Pond 2 Runoff

Area = 5.7 acres with domed surface

→ 1/2 of surface will contribute flow to the diversion along the south side of Pond 2

→ North half runoff will be overland (not channeled) flow

Area = 2.9 acres = 0.0045 sq mi

SCS CN = 83

Basin slope = 1%

Drainage length = 280 ft (typ)

Lag Time = 0.904 hrs

HECLA MINING COMPANY

COEUR D'ALENE, IDAHO 83814

BY DTM	DATE 5/26/03	JOB TITLE APEX Pond Z Closure	JOB NO.
CHK.	DATE		DIVISION
DWG. NO.		Runoff Calcs	SHEET 8 OF 14

Sub Basin Characteristics

West A = 3.6ac 0.0056mi² hyd L =

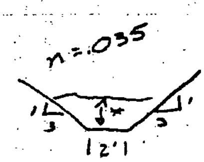
ID	Name	Area (ac)	Area (mi^2)	Hyd L (ft)	Slope (ft/ft)		SCS Lag Time (min) calc on p8/
1	West	3.6	.0056	920	(3712-3674)/L	= 0.041	8
2	East-1	6.2	.0097	1,300	3865-3706/L	= 0.122	6
3	East-2	9.7	.0152	1,250	(3710-3674)/L	= 0.029	12
4	East-3	10.8	.0169	1,100	3850-3705/L	= 0.132	5
5	East-4	5.6	.0088	500	3705-3675/L	= 0.060	4

Routing Parameters Muskingham 'K & X'

West – flows to west; no combination, no routing

East-1 route through East-2 950 ft @ 10/480 2.1% ~ 5.5 cfs

East-2 route through East-4 along south edge of Pond Z
500 ft @ ~1% 12.3 cfs

East-3 route through East-4 all w/ 
400 ft @ 5% ~ 9.9 cfs

Route	Q (cfs)	Slope (ft/ft)	Depth* (ft)	Velocity (fps)	K hrs	X
E-1 to E-2	5.5	.021	0.51	3.0	.088	.319
E-2 to E-4	12.3	.01	0.91	2.9	.046	.319
E-3 to E-4	9.9	.05	0.55	4.9	.022	.373

K & X calculated on spreadsheet see p 12/

velocity calculated on spreadsheet see p 1P/

THIS SPREADSHEET CALCULATES LAG TIME FOR BASINS.
IT CAN BE USED FOR HEC-1 ANALYSES.

LAG TIME = L^0.8*(S+1)^0.7/1900*Y^0.5
L = GREATEST SLOPE LENGTH (FEET)
S = (1000/n) - 10 = 2.05
n = CURVE NUMBER = 83
Y = AVERAGE BASIN SLOPE

BASIN	L (FT)	Y (%)	LAG TIME (HRS)	LAG TIME (MIN)
APEX Pond 2 Closure				
South Pond	280	1	0.104	6.251
East-1	1300	12.2	0.102	6.112
East-2	1250	2.9	0.202	12.149
East-3	1100	13.2	0.086	5.141
East-4	500	6	0.068	4.058

HMS * Summary of Results

Project : Hecla_APEX   Run Name : Run 1

Start of Run   : 01Jun03 1200   Basin Model   : Basin 1
End of Run   : 02Jun03 1200   Met. Model   : Met 1
Execution Time   : 26May03 1813   Control Specs : Control 1

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
West	2.9026	01 Jun 03 1634	0.18747	0.006
East-2	6.8140	01 Jun 03 1636	0.50882	0.015
East-4	5.3962	01 Jun 03 1631	0.29459	0.009
East-1	5.4478	01 Jun 03 1632	0.32472	0.010
East-3	9.9064	01 Jun 03 1632	0.56572	0.017

Calculation of basin peak flows

- no reaches or routing included.

Trial and Error method for calculating depth and the corresponding velocity using Manning's Equation.

Flow =	9.9 cfs
Manning's n =	0.035
Bottom width =	2 ft
Right Side Slope, z:1 =	3
Left Side Slope, z:1 =	3
Channel Slope =	0.05 ft/ft

Trapezoidal Channel

Assumed Depth (ft)	Calculated Depth (ft)	Average Velocity (ft/s)	Type of Flow	Froude Number	Cross-Sectional Area	Top Width	Hydraulic Radius
1.00	0.29						
0.65	0.47						
0.56	0.55						
0.55	0.55	4.89	SUPERCRITC	1.3968	2.02	5.32	0.15
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Sample velocity calc
for determination of
Muskingham K & x

THIS SPREAD SHEET CAN BE USED TO CALCULATE MUSKINGHAM ROUTING NUMBERS "K" AND "X"

X = (0.5*V)/(1.7+V)   0 < X < 0.5
K = L/V/3600 (SEC TO HRS)
V = ESTIMATED VELOCITY FOR FIRST TRIAL (BARFIELD)
AND CALCULATED VELOCITY AFTER RUNNING HEC.
L = CHANNEL LENGTH

REACH	VELOCITY (FT/S)	LENGTH (FT)	K (HRS)	X
e1-e2	3	950	0.088	0.319
e2-e4	3	500	0.046	0.319
e3-e4	5	400	0.022	0.373
N1-N2	6	400	0.019	0.390
N1-N2	7	400	0.016	0.402
N1-N2	8	400	0.014	0.412
N1-N2	9	400	0.012	0.421
N1-N2	10	400	0.011	0.427
N1-N2	11	400	0.010	0.433
N1-N2	12	400	0.009	0.438
N1-N2	13	400	0.009	0.442
N1-N2	14	400	0.008	0.446

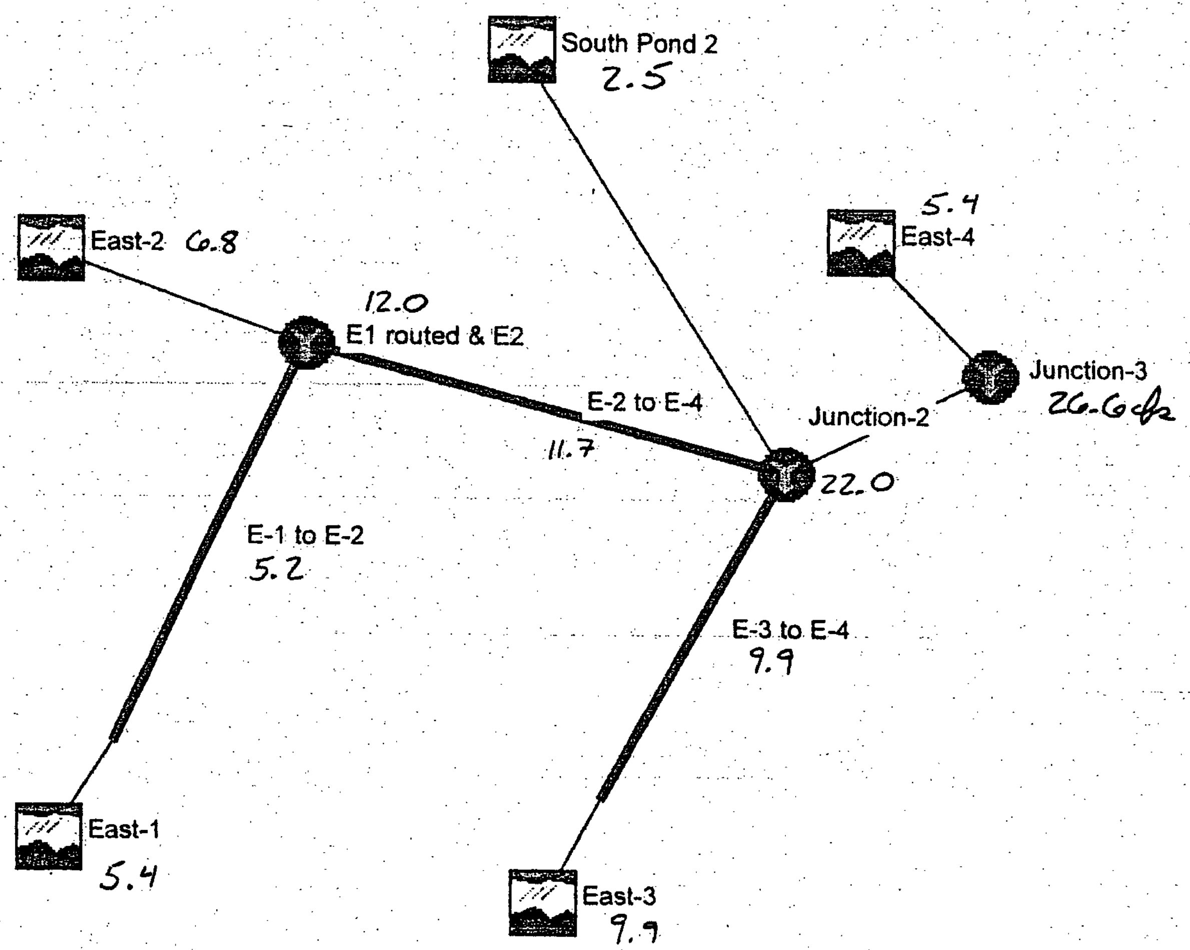
THE TABLE BELOW WILL SHOW IF THERE IS ANY POTENTIAL ROUTING INSTABILITY

(K * 60)/(NMIN * NSTPS)   = MT   IDDLE TER
MUST BE BETWEEN THE FOLLOWING TWO LIMITS:
LOWER LIMIT =   1/(2(1-X))   = LL
UPPER LIMIT =   1/(2X)   = UL
NSTPS =   1)er of subreaches)
NMIN =   2 *tes in computational interval)*
IF THERE IS INSTABILITY, EITHER REDUCE NSTPS OR NMIN.

VELOCITY (FT/S)	K (HRS)	X	LL	UL	MT
3	0.088	0.319	0.734	1.57	2.64
3	0.046	0.319	0.734	1.57	1.39
5	0.022	0.373	0.798	1.34	0.67
6	0.019	0.390	0.819	1.28	0.56
7	0.016	0.402	0.837	1.24	0.48
8	0.014	0.412	0.851	1.21	0.42
9	0.012	0.421	0.863	1.19	0.37
10	0.011	0.427	0.873	1.17	0.33
11	0.010	0.433	0.882	1.15	0.30
12	0.009	0.438	0.890	1.14	0.28
13	0.009	0.442	0.896	1.13	0.26
14	0.008	0.446	0.902	1.12	0.24

P12/14

25 YR 6HR 1.9 IN Storm Event Peak Flows (cfs)

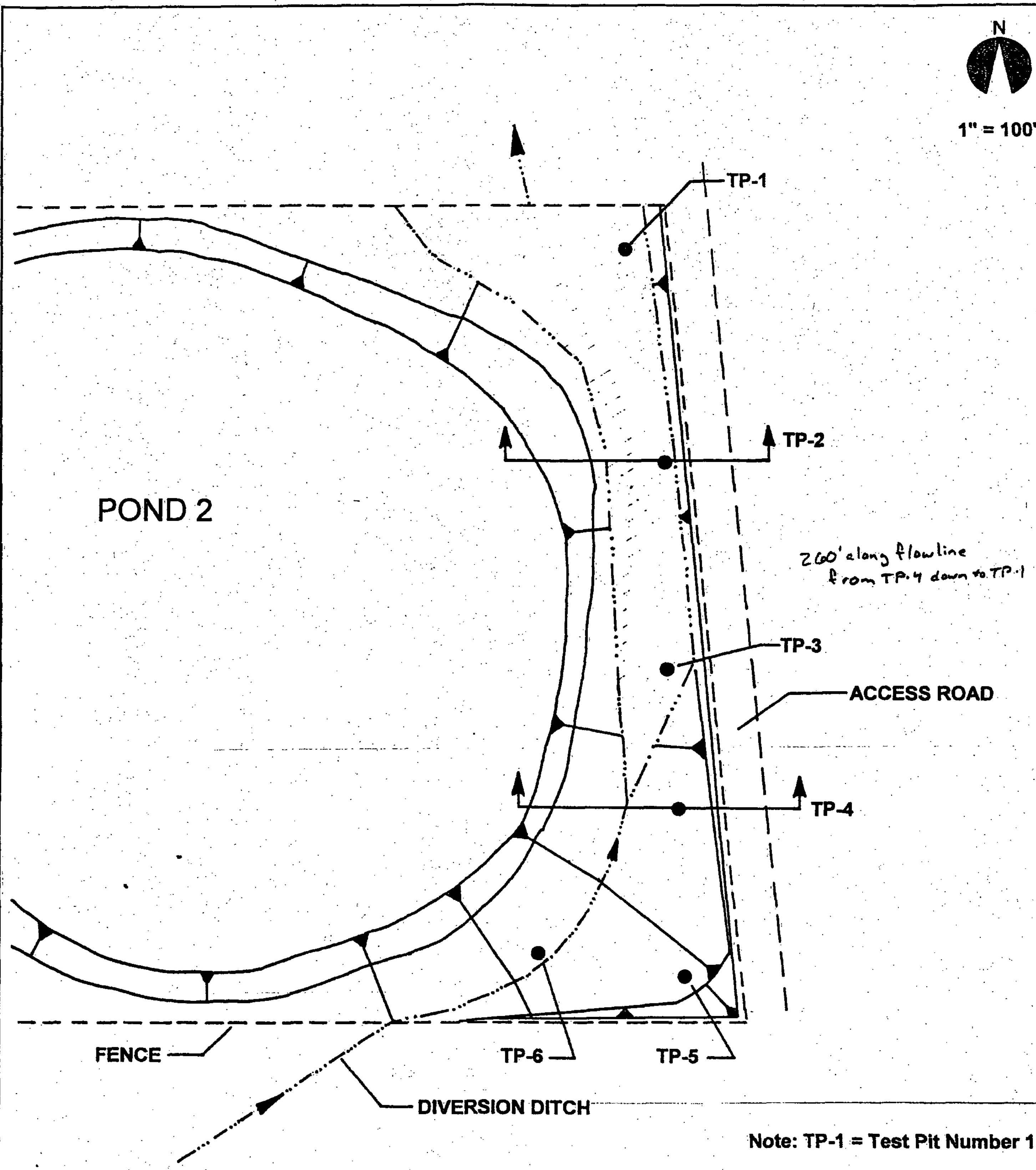


HMS * Summary of Results

Project : Hecla_APEX   Run Name : Run 1

Start of Run   : 01Jun03 1200   Basin Model   : Basin 1
End of Run   : 02Jun03 1200   Met. Model   : Met 1
Execution_Time   : 01Jun03 1445   Control Specs : Control 1

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
East-1	5.4478	01 Jun 03 1632	0.32472	0.010
E-1 to E-2	5.1581	01 Jun 03 1636	0.32472	0.010
East-2	6.8140	01 Jun 03 1636	0.50882	0.015
E1 routed & E2	11.972	01 Jun 03 1636	0.83354	0.025
E-2 to E-4	11.727	01 Jun 03 1639	0.83354	0.025
East-3	9.9064	01 Jun 03 1632	0.56572	0.017
E-3 to E-4	9.8512	01 Jun 03 1633	0.56572	0.017
South Pond 2	2.5274	01 Jun 03 1632	0.15065	0.004
Junction-2	22.043	01 Jun 03 1634	1.5499	0.046
East-4	5.3962	01 Jun 03 1631	0.29459	0.009
Junction-3	26.643	01 Jun 03 1633	1.8445	0.055



PROJECT APEX
LOCATION St. George, Utah
DATE 3/15/03

Figure 9

Alternative 1 - Channel Excavation Plan View

Prepared by:

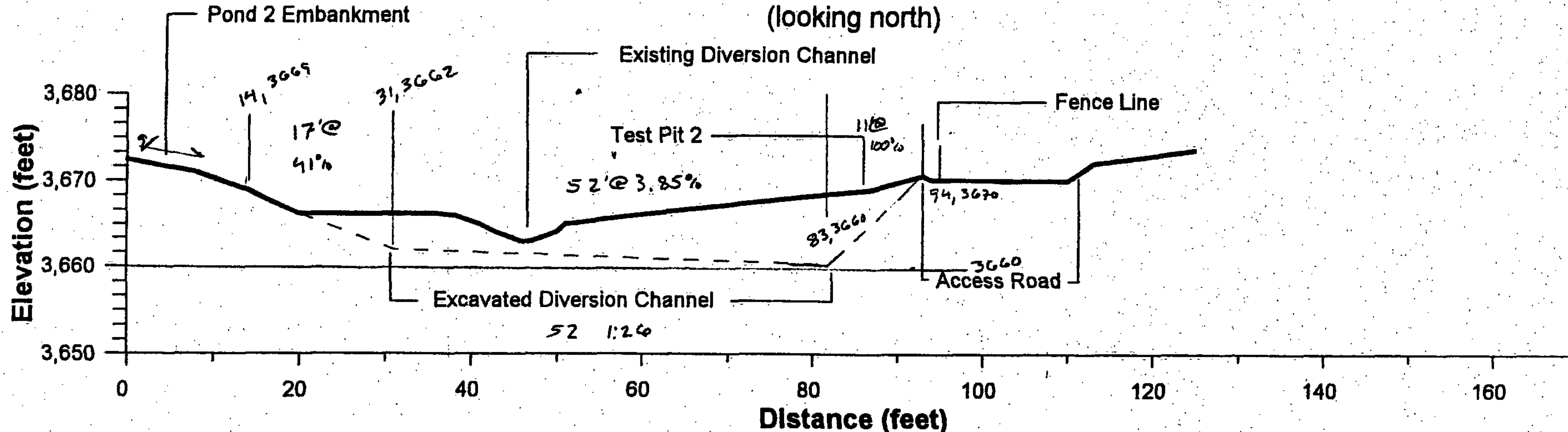
Monster Engineering Inc.

Prepared for:

Hecla MINING COMPANY

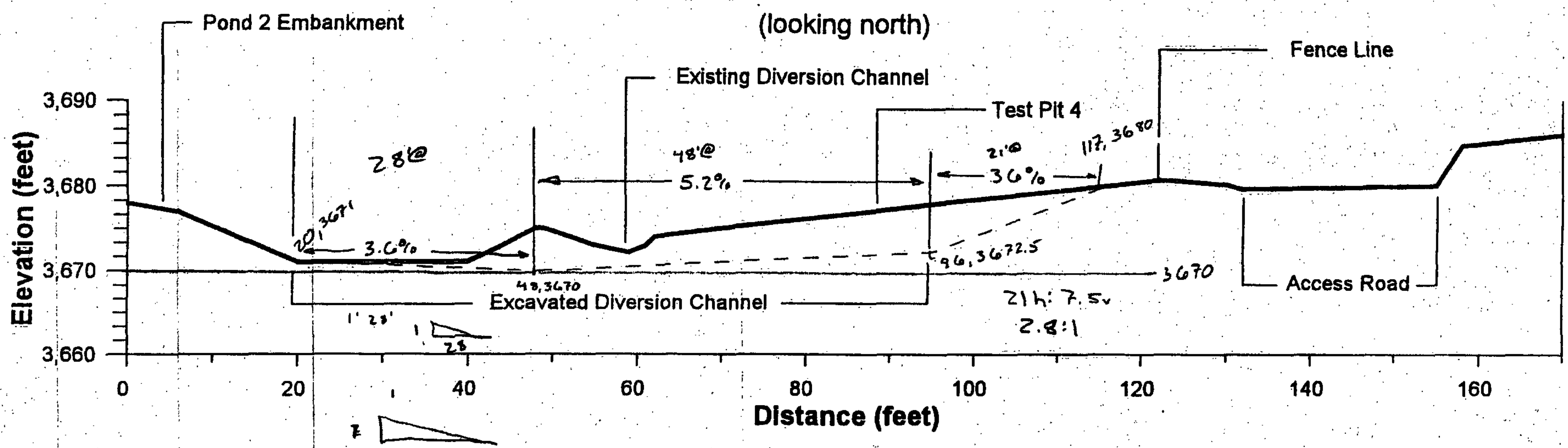
Channel Cross-section at TP- 2

(looking north)



Channel Cross-section at TP- 4

(looking north)



1" = 20' Horizontal = Vertical

PROJECT	APEX
LOCATION	St. George, Utah
DATE	3/15/03

Figure 8

Alternative 1 - Borrow Area / Channel Excavation Cross Sections

Prepared by:

Monster Engineering Inc.

Prepared for:

Hecla MINING COMPANY

HECLA MINING COMPANY

COEUR D'ALENE, IDAHO 83814

BY DTM	DATE 6/22/03	JOB TITLE Apex Pond 2 Closure	JOB NO.
CHK.	DATE		DIVISION
DWG. NO.		Reclaimed South Ditch	SHEET 1 OF 7

- HEC-HMS analysis of 25YR 6HR Storm event gave a peak flow at south side of 22cfs and peak flow at southeast side of 26.6cfs
- Utilize peak flow of 27cfs

- Geometry of diversion given by Figure 8 (@ TP-2 & TP-4) MCI closure alternatives

Section	left slope	rt slope	invert elev	distance between TP-4 &
TP-2 d/s	3.85% 1:26	1:1 100%	3660.5	TP-2 = 260' slope
TP-4 u/s	3.6 1:28h	36% 28h:1v	3670 28h:1v	= 9.5/260' = 3.65%

- Manning's n value Schwab (1981)
  use $n = 0.030$

- Spreadsheet analysis of depth & velocity see p 2/ & 3/

Section	Depth (ft)	Velocity (fps)
TP-4	0.63	4.4
TP-2	0.67	4.5

Soil shear stress

soil grain roughness

Sample TP-1 68% minus No 200

$D_{75} = 0.1m = 0.0039in$

$n_s = \frac{(D_{75})^{1/6}}{39}$ $n_s = 0.0102$ shear stress cont'd on p 4/

Trial and Error method for calculating depth and the corresponding velocity using Manning's Equation

Flow =	27	cfs
Manning's n =	0.03	
Left Side Slope Z:1=	28	
Right side slope Z:1=	2.8	
Channel Slope =	0.0365	ft/ft

@ TP-4

Triangular Channel

Assumed Depth (ft)	Calculated Depth (ft)	Average Velocity (ft/s)	Type of Flow
1000.00	0.05		
0.05	1.43		
1.43	0.48		
0.48	0.69		
0.69	0.61		
0.61	0.64		
0.64	0.63		
0.63	0.63	4.4	SUBCRITICAL FLOW
	#DIV/0!	#DIV/0!	#DIV/0!

P2/7

Trial and Error method for calculating depth and the corresponding velocity using Manning's Equation

@ TP-Z

Flow =	27 cfs
Manning's n =	0.03
Left Side Slope Z:1=	26
Right side slope Z:1=	1
Channel Slope =	0.0365 ft/ft

Triangular Channel

Assumed Depth (ft)	Calculated Depth (ft)	Average Velocity (ft/s)	Type of Flow
1000.00	0.06		
0.06	1.50		
1.50	0.51		
0.51	0.73		
0.73	0.65		
0.65	0.67		
0.67	0.66		
0.66	0.67		
0.67	0.67	4.5	SUBCRITICAL FLOW

HECLA MINING COMPANY

COEUR D'ALENE, IDAHO 83814

BY DTM DATE 6/2/03	JOB TITLE APEX POND 2 Closure	JOB NO.
CHK. DATE		DIVISION
DWG. NO.	South Ditch Analysis	SHEET 4 OF 7

Erosional Stability of Channel Soils By Temple Shear Stress Method (1987)

$\tau_a = \tau_{ab} C_e^2$ τ_a = allowable shear stress (psf)

τ = ~~atto~~ basis allowable shear stress (psf)

C_e = soil parameter $= A - B_e$

τ_{ab} silts & clays = 0.076

& $C_e = 1.42 - 0.61e$

e = void ratio $= \dfrac{V_v}{V_s} = \dfrac{V_A + V_w}{V_s}$

		0.22	Air	
$V_T = 1.0\,ft^3$	.356	0.136	Water	$W_w = 8.5$ lb; $W_T = 115$ lb
		0.644	Solids	$W_s = 106.5$ lb

Assume soil w/in channel $\gamma_m = 115$ pcf @ $w = 8\%$ $\gamma_d = 106.5$ pcf

$V_w = \dfrac{W_w}{\gamma_w} = 8.5\,\text{lb} \left| \dfrac{ft^3}{62.4\,\text{lb}} \right| = 0.136\,ft^3$

$V_s = \dfrac{W_s}{G_s \gamma_w}$ assume $G_s = 2.65$ $V_s = \dfrac{106.5\,\text{lb}}{(62.4\,\text{pcf})\,2.65} = 0.644$

$e = \dfrac{0.356}{0.644} = 0.55$

→ Spread sheet calculation see p 4/

All calculated values τ_a/τ_{eff} are > 1 indicating stability of soils within the channel should not be dislodged by hydraulic forces exerted under the 25YR 6HR storm

However, limited Site, surface soil information is available. Rather than creating an entrenched armoured channel, the more effective method to ensuring pile stability would be to entrench slope erosion materials below the existing/reclaimed ground surface level.

SPREADSHEET TO CALCULATE ALLOWABLE AND EFFECTIVE
SHEAR STRESSES (Temple et al., 1987)

PROJECT APEX Pond 2 Closure
AREA South Channel
DATE 6/22/2003

<========E Q U A T I O N=== ========>

Ta = Tab*Ce^2

Ta = allowable shear stress (psf)
Tab = basis allowable shear stress (psf)
Ce = soil parameter = A-Be
e = void ratio NOTE: Equation will vary depending on soil type
check Temple et al.

<========C A L C U L A T I O N====>

input values		output value	
A	1.42	Ce	1.0845
B	0.61		
e	0.55	Ta	0.0894
Tab	0.076		

<========E Q U A T I O N=== ======== ======== ===>

Effective Shear Stresses

Teff = YDS(1-Cf)(ns/n)^2

Teff = effective shear stress (psf)
Y = unit weight of water (pcf)
D = depth of flow (ft)
S = bed slope (ft/ft)
Cf = vegetal cover factor
ns = soil grain roughness factor = D75^(1/6)/39
n = Manning's "n"

Conquista:

Cf good cover = 0.9
Cf bare soil = 0.5

<======== ======== C A L C U L A T I O N====== ======== ======== ========>

SECTION	Y	D	S	Cf	ns	n	Teff	Ta/Teff
TP-4	62.4	0.63	0.0365	0.6	0.0102	0.03	0.0663	1.347
TP-2	62.4	0.67	0.0365	0.6	0.0102	0.03	0.0706	1.267

RIP RAP CALULATION USING: SAFETY FACTORS AND CORPS OF ENGINEERS METHODS
Cross-Section TP-4

WATER DEPTH=? (ft.)	0.63		
	RISE/RUN	RADS	DEGREES
BED SLOPE=? (RISE/RUN)	0.0365	0.036	2.09
BANK SLOPE=? (RISE/RUN) left (Pond 2 side)	0.036	0.036	2.06
ANGLE OF REPOSE=? (DEGREES)		0.698	40.00

VEL. = ? 4.4 (fps)

CORPS OF ENGINEERS METHOD

D-50 (ft)	DEPTH (ft)	T TRACTIVE FORCE	N STABILITY PARAMETER	B (RADS)	B DEGREES	N'	SAFETY FACTOR	VEL. (fps)	T NEEDED TRACTIVE FORCE	T AVAILABLE	T SLOPE	SF
0.04	0.63	1.09	5.56	1.56	89.12	5.56	0.18	4.4	0.22	0.16	0.164	0.75
0.06	0.63	1.09	3.71	1.55	88.69	3.71	0.27	4.4	0.26	0.25	0.246	0.96
0.08 1"	0.63	1.09	2.78	1.54	88.26	2.78	0.36	4.4	0.29	0.33	0.328	1.13
0.17	0.63	1.09	1.31	1.51	86.37	1.31	0.76	4.4	0.41	0.70	0.697	1.68
0.25 3"	0.63	1.09	0.89	1.48	84.75	0.89	1.12	4.4	0.51	1.03	1.024	1.99
0.33	0.63	1.09	0.67	1.45	83.18	0.67	1.47	4.4	0.61	1.35	1.352	2.22
0.42	0.63	1.09	0.53	1.42	81.48	0.53	1.87	4.4	0.71	1.72	1.721	2.41
0.50	0.63	1.09	0.44	1.40	80.03	0.44	2.22	4.4	0.81	2.05	2.049	2.54
0.12	0.63	1.09	1.85	1.53	87.41	1.85	0.54	4.4	0.35	0.49	0.492	1.41

PG/7

RIP RAP CALULATION USING: SAFETY FACTORS AND CORPS OF ENGINEERS METHODS

Cross-Section TP-2

WATER DEPTH=? (ft.) 0.67

	RISE/RUN	RADS	DEGREES
BED SLOPE=? (RISE/RUN)	0.0365	0.036	2.09
BANK SLOPE=? (RISE/RUN) left (Pond 2 side)	0.0385	0.038	2.20
ANGLE OF REPOSE=? (DEGREES)		0.698	40.00

VEL. = ? 4.5 (fps)

CORPS OF ENGINEERS METHOD

D-50 (ft)	DEPTH (ft)	T TRACTIVE FORCE	N STABILITY PARAMETEI	B (RADS)	B DEGREES	N'	SAFETY FACTOR	VEL. (fps)	T NEEDED TRACTIVE FORCE	T AVAILABLE	T SLOPE	SF
0.04	0.67	1.16	5.91	1.56	89.12	5.91	0.17	4.5	0.22	0.16	0.164	0.74
0.06	0.67	1.16	3.94	1.55	88.68	3.94	0.25	4.5	0.26	0.25	0.246	0.94
0.08	0.67	1.16	2.96	1.54	88.25	2.96	0.34	4.5	0.29	0.33	0.328	1.11 1"
0.17	0.67	1.16	1.39	1.51	86.34	1.39	0.72	4.5	0.42	0.70	0.696	1.66
0.25	0.67	1.16	0.95	1.48	84.70	0.95	1.05 3"	4.5	0.52	1.03	1.024	1.98
0.33	0.67	1.16	0.72	1.45	83.12	0.72	1.39	4.5	0.61	1.35	1.352	2.21
0.42	0.67	1.16	0.56	1.42	81.40	0.56	1.76	4.5	0.72	1.72	1.721	2.41
0.50	0.67	1.16	0.47	1.39	79.93	0.47	2.09	4.5	0.81	2.05	2.048	2.54

P 7/7

HECLA MINING COMPANY

COEUR D'ALENE, IDAHO 83814

BY DTM	DATE 6/22/03	JOB TITLE APEX POND 2 CLOSURE	JOB NO.
CHK.	DATE		DIVISION
DWG. NO.		POND 2 Runoff/Erosional stability	SHEET 1 OF 5

Consider a 50-ft wide strip of pond surface

length of top surface = 280' @ 1%

Area = 280' × 50' = 14,000 sq ft = 0.32 ac = 0.0005 sq mi

use CN = 83 rock/gravel surface underlain by compacted fill

increase over rock layer value for added conservatism to runoff/erosional stability calculations

SCS Lag Time = 6 minutes

→ 25YR 6HR 1.9" Storm peak runoff = 0.28 say 0.3 cfs

To account for variations in surface grading & resulting topography use concentration factor

∴ peak flow from 50' unit width = 3 × 0.3 cfs = 0.9 cfs ↗ 1 cfs

or $\frac{1 cfs}{50 ft}$ = 0.02 cfs/ft

Reclaimed Pond 2 outslopes 3.5h:1v or 28.6%

→ use Manning spreadsheet to calculate depth of flow & velocity @ 1% & 28.6% slopes

n = 0.04 flow w/in rock cover

q = 1 cfs

n = 0.04

B_w = 50'

S = 1%	S = 28.6%
Depth = 0.04 ft	Depth = 0.02 ft
Vel = 0.5 fps	Vel = 1.25 fps

Outslope rock sizes

Safety Factors ≥ 3/4" D_{50}

COE Method 1/4" & 1/2" D_{50} are ok

≥3/4" method calcs blow up

HMS * Summary of Results

Project : Hecla_APEX   Run Name : Run 2

Start of Run : 01Jun03 1200   Basin Model : Pond 2 unit runoff
End of Run : 02Jun03 1200   Met. Model : Met 1
Execution Time : 03Jun03 2038   Control Specs : Control 1

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
50' width unit runof	0.28083	01 Jun 03 1632	0.016739	0.001

→ decimal resolution
to 3 decimal places
actual area used in
model = 0.0005 sq mi

P 2/5

Trial and Error method for calculating depth and the corresponding velocity using Manning's Equation.

Flow =	1	cfs
Manning's n =	0.04	
Bottom width =	50	ft
Right Side Slope, z:1 =	0.01	
Left Side Slope, z:1 =	0.01	
Channel Slope =	0.286	ft/ft

Trapezoidal Channel

Assumed Depth (ft)	Calculated Depth (ft)	Average Velocity (ft/s)	Type of Flow	Froude Number	Cross-Sectional Area	Top Width	Hydraulic Radius
1.00	0.00						
0.50	0.00						
0.25	0.00						
0.13	0.00						
0.07	0.01						
0.04	0.01						
0.02	0.01						
0.02	0.01						
0.02	0.02	1.25	SUPERCRITC	1.7556	0.78	50.00	0.01

Trial and Error method for calculating depth and the corresponding velocity using Manning's Equation.

Flow =	1	cfs
Manning's n =	0.04	
Bottom width =	50	ft
Right Side Slope, z:1 =	0.01	
Left Side Slope, z:1 =	0.01	
Channel Slope =	0.01	ft/ft

Trapezoidal Channel

Assumed Depth (ft)	Calculated Depth (ft)	Average Velocity (ft/s)	Type of Flow	Froude Number	Cross-Sectional Area	Top Width	Hydraulic Radius
1.00	0.01						
0.50	0.01						
0.26	0.01						
0.13	0.02						
0.08	0.03						
0.05	0.04						
0.05	0.04						
0.04	0.04	0.46	SUBCRITICAI	0.3884	2.16	50.00	0.02
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

4/5

RIP RAP CALULATION USING: SAFETY FACTORS AND CORPS OF ENGINEERS METHODS
Pond 2 reclaimed 3.5h:1v outslope
WATER DEPTH=? (ft.) 0.02

	RISE/RUN	RADS	DEGREES
BED SLOPE=? (RISE/RUN)	0.286	0.279	15.96
BANK SLOPE=? (RISE/RUN)	0.1	0.100	5.71
ANGLE OF REPOSE=? (DEGREES)		0.698	40.00

VEL. = ? 1.25 (fps)

CORPS OF ENGINEERS METHOD

D-50 (ft)	DEPTH (ft)	T TRACTIVE FORCE	N STABILITY PARAMETER	B (RADS)	B DEGREES	N'	SAFETY FACTOR	VEL. (fps)	T NEEDED TRACTIVE FORCE	T AVAILABLE	T SLOPE	SF
0.02	0.02	0.27	2.77	1.49	85.44	2.74	0.36	1.25	0.08	0.08	0.081	1.04 < 3/4"
0.04	0.02	0.27	1.38	1.43	81.80	1.38	0.71	1.25	0.15	0.16	0.162	1.09
0.06	0.02	0.27	0.92	1.38	78.84	0.92	1.05 3/4"	1.25	0.25	0.25	0.243	0.98
0.08	0.02	0.27	0.69	1.33	76.40	0.69	1.38	1.25	0.39	0.33	0.324	0.83
0.17	0.02	0.27	0.33	1.21	69.31	0.32	2.71	1.25	3.72	0.70	0.689	0.19
0.25	0.02	0.27	0.22	1.15	65.81	0.22	3.70	1.25	824.23	1.03	1.014	0.00
0.33	0.02	0.27	0.17	1.11	63.53	0.17	4.54	1.25	5.34	1.35	1.338	0.25

P 5/5

Appendix G

Cost Estimate

Appendix G - Cost Estimate

Summary

The estimated range of total construction costs to implement Hecla's Selected Alternative (GCL) as the Final Closure Plan at the Apex Site is $341,670 to $400,967. The estimated range of total construction costs to implement Hecla's Modified Alternative (Blue Clay) as the Final Closure Plan at the Apex Site is $288,670 to $366,667. Major cost items for the Selected Alternative are summarized in Table 1 on the following page. This table also contains details of quantities, unit prices, and delivery and placement costs. This estimated range is based on the assumption that all construction work will be conducted by outside contractors.

Unit prices for earthwork activities and materials were based on cost estimates provided by local and national vendors (NILEX 2003) (Kaul 2003), local material prices, and local equipment rates (L & M 2003) (Progressive 2003). Any unit prices required for this cost estimate that could not be based on actual bids were derived from the Caterpillar Performance Book (Caterpillar 1994), Estimating Excavation (Burch 1997), and construction experience.

Table 2 (second page following) contains a breakdown of estimated equipment type and hours required to complete each major work item. Table 3 contains equipment rates from the St. George area which were utilized in this cost estimate.

References

Burch 1997. D. Burch, Estimating Excavation, Craftsman Book Company, Carlsbad, CA.

Caterpillar 1994. Caterpillar Performance Book, Caterpillar, Inc., Peoria, Illinois.

Kaul 2003. Kaul Corporation, Lakewood, CO, *CETCO GCL Quotation, August 2003.*

L& M 2003. L & M General Engineering and Construction, Inc., St. George, UT, *Equipment Rental List, February 2003.*

NILEX 2003. NILEX Corporation, Englewood, CO, *Mebra Drain Vertical Wick Quotation, August 2003.*

Progressive 2003. Progressive Contracting Inc., St. George, UT, *Trucking Quotation, January 2003.*

Table 1
Cost Estimate - Selected Alternative (GCL)

Item #	Item	Quantity	Units	Purchase/ Excavation ($/Unit)	Deliver ($/Unit)	Place ($/Unit)	Total ($/Unit)	Estimated Cost Range	
								Low	High
1	Mobilization - Earthmoving Contractor	1	LS	$2,000	NA	NA	$2,000	$2,000	$2,400
	Phase I - Drainge & Consolidation								
2	Construct Exterior Containment Berm	1	LS	NA	$0	$300	$300	$300	$450
3	Fabricate and Install Settlemement Monuments	6	EA	$50	$0	$200	$250	$1,500	$1,800
4	Install Vertical Wick Drains @ 4 O.C.	200,000	LF	$0.43	$0.075	$0.00	$0.51	$101,000	$111,100
5	Construct Interior Containment Berms @ 30' O.C.	1	LS	NA	$0	$1,280	$1,280	$1,280	$1,664
6	Remove & Dispose Evaporated Salts (top surface)	1	LS	NA	$0	$1,200	$1,200	$1,200	$2,400
7	Remove & Dispose Evap Pond/Coll. Ditch Materials	1	LS	NA	$0	$1,500	$1,500	$1,500	$2,250
	Phase II - Regrading								
8	Excavate Existing Embankment	9,300	CY	NA	$0	$0.56	$0.56	$5,250	$7,875
9	Place Preloading on Top Surface	9,300	CY	NA	$0	$0.32	$0.32	$3,000	$3,600
10	Final Grading of 1% Surface	9,300	CY	NA	$0	$0.24	$0.24	$2,250	$3,150
	Phase III - Final Cover System Construction								
11	Mobilization - GCL Contractor / Installer	1	LS	$2,500	$0.00	$0.00	$2,500	$2,500	$3,000
12	Place Barrier Layer (GCL) - top	195,750	SF	$0.25	$0.05	$0.10	$0.40	$78,000	$85,800
13	Place Barrier Layer (GCL) - outslopes	49,500	SF	$0.31	$0.05	$0.10	$0.46	$23,000	$25,300
14	Strip & Grub Vegetation	1	LS	$0.00	$0.00	$2,250	$2,250	$2,250	$2,700
15	Excavate Diversion Channel	11,500	CY	$0.65	$0.26	$0.00	$0.91	$10,500	$12,600
16	Place Protection Layer (12" on-site materials)	8,000	CY	$0.00	$0.25	$0.56	$0.81	$6,500	$10,400
17	Reconstruct Outside Embankment	3,500	CY	$0.00	$0.29	$1.81	$2.10	$7,350	$11,025
18	Finish Grade 1% Surface - top	1	LS	$0.00	$0.00	$2,250	$2,250	$2,250	$4,500
19	Place Surface Layer (outslopes only) D50 = 1"	300	CY	$7.00	$4.00	$5.00	$16.00	$4,800	$5,760
20	Place Diversion Channel Erosion Protection (3" rock)	200	CY	$7.00	$4.20	$7.75	$18.95	$3,790	$4,548
21	Dust / Erosion Control	1	LS	$2,700	NA	NA	$2,700	$2,700	$2,970
22	QA / QC	60	Days	$650	NA	NA	$650	$39,000	$46,800
23	Construction Management	60	Days	$500	NA	NA	$500	$30,000	$33,000
24	Surveying (Settl. Mon., All Surfaces)	15	Days	$800	NA	NA	$800	$12,000	$18,000
							Totals	**$343,920**	**$400,692**

Table 2
Cost Estimate - Equipment Hours Breakdown

Item #	Item	Equipment Utilized, Hourly Rate, and Hours Required												Total Equip. Cost	Misc. Costs		Total Cost
		Ldr $75	Exc $125	Scr $70	D5 Dzr $75	D7 Dzr $85	T.Trk $75	S.D. Trk $50	L.D. Trk $60	Bld $75	W.Trk $45	Bkh $50	Comp $50				
1	Mobilization - Earthmoving Contractor						14							$1,050	Trlr. Rent.	$950	$2,000
	Phase I - Drainge & Consol.																
2	Construct Exterior Containment Berm									4				$300			$300
3	Fab. / Inst. Settlemement Monuments											24		$1,200	Fabricate	$300	$1,500
4	Install Vertical Wick Drains @ 4 O.C.													$0	Purch./Inst.	$101,000	$101,000
5	Constr. Int. Cont. Berms @ 30' O.C.					8				8				$1,280			$1,280
6	Remove & Dispose Evap. Salts	8								8				$1,200			$1,200
7	Rem. & Disp. Evap. Pond/Coll. Ditch		4					10				10		$1,500			$1,500
	Phase II - Regrading																
8	Excavate Existing Embankment		30					30						$5,250			$5,250
9	Place Preloading on Top Surface							30		20				$3,000			$3,000
10	Final Grading of 1% Surface									30				$2,250			$2,250
	Phase III - Fnl. Cover Sys.																
11	Mobilization - GCL Contr.													$0	Mob.	$2,500	$2,500
12	Place Barrier Layer (GCL) - top													$0	Install	$78,000	$78,000
13	Place Barrier Layer (GCL) - outslps													$0	Install	$23,000	$23,000
14	Strip & Grub Vegetation		10					20						$2,250			$2,250
15	Excavate Diversion Channel		60					60						$10,500			$10,500
16	Place Protection Layer							40		60				$6,500			$6,500
17	Reconstruct Outside Embankment				10	10		20		50			20	$7,350			$7,350
18	Finish Grade 1% Surface - top									30				$2,250			$2,250
19	Place Surface Layer (outslopes only)				20				20					$2,700	Purchase	$2,100	$4,800
20	Place Div. Ch. Eros. Prot. (3" rock)		10						14	4				$2,390	Purchase	$1,400	$3,790
21	Dust / Erosion Control										60			$2,700			$2,700
22	QA / QC													$0	QA / QC	$39,000	$39,000
23	Construction Management													$0	CM	$30,000	$30,000
24	Surveying (Settl. Mon., All Surfaces)													$0	Surveying	$12,000	$12,000
	Totals	8	104	0	30	18	14	190	34	214	60	34	20	$53,670		$290,250	$343,920

Table 3
Estimated Equipment Rates[1]

Equipment	Abbreviation	Hourly Rate[2]
950 F Cat Loader	Ldr	$75
325 Cat Excavator	Exc	$125
Cat Scraper	Scr	$70
Cat D5 Dozer Wide Track	D5 Dzr	$75
Cat D7 Dozer	D7 Dzr	$85
Transport Truck	T. Trk	$75
Small Dump Truck	S.D. Trk	$50
Large Dump Truck	L.D. Trk	$60
Cat 12G Blade	Bld	$75
Water Truck	W. Trk	$45
JD Backhoe	Bkh	$50
Self-propelled Sheep's Foot Compactor	Comp	$50

1 - Approximate rates for St. George, Utah as of February 2003.
2 - All rates include operator.

Appendix H

Long-Term Monitoring and Maintenance Plan

Appendix H - Long-Term Monitoring and Maintenance Plan

Summary

This Long-Term Monitoring and Maintenance Plan details steps to be taken to ensure continued integrity and effectiveness of the Pond 2 final cover system at Hecla Mining Company's Apex Site. The key elements of the plan are:

- detection methods (monitoring schedule and site inspection methods)
- allowable limits (guidelines for interpreting monitoring results)
- remediation plan when/if limits are exceeded (list of preventative maintenance activities)

The plan contains the following items:

- monitoring schedule and site inspection methods
- guidelines for interpreting monitoring results
- list of preventative maintenance activities

Also included in this plan are a site inspection checklist and forms for the annual site inspections.

Monitoring Schedule and Site Inspection Methods

Site inspections will provide early warning of potential problems which could impact the final cover system's integrity. The Apex Site should be inspected annually to verify that the final cover system is functioning properly and to ensure that no significant problems are developing. The monitoring period may require adjustment based on data collected from the first inspection, as monitoring periods are a function of the stability of the waste and cover system.

Areas to be inspected annually include:

- Site Perimeter - site boundary and outlying areas up to 1/4 mile beyond Hecla's fence line. This includes the property fence, site entrance gate, and all upgradient drainage areas.
- Impoundment - top and outslopes, Protection Layer (top surface materials), and Surface Layer (erosion protection)
- Diversion Channel - erosion protection, normal flow channel, intersections with site perimeter fencing

The primary purpose of the annual inspection will be to look for evidence of significant movement of materials such as:

- cover subsidence
- excessive slope movement or failure
- gully development
- excessive siltation
- leachate migration

Appendix H - Long-Term Monitoring and Maintenance Plan

Summary

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Monitoring Schedule and Site Inspection Methods

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- Diversion Channel - erosion protection, normal flow channel, intersections with site perimeter fencing

The primary purpose of the annual inspection will be to look for evidence of significant movement of materials such as:

- cover subsidence
- excessive slope movement or failure
- gully development
- excessive siltation
- leachate migration

Guidelines for Interpreting Monitoring / Inspection Results

Table 1 on the following page contains details of how monitoring / inspection results should be interpreted, sets allowable limits, and provides an outline for repair activities required if allowable limits are exceeded.

Table 1 Problem Identification, Allowable Limits, and Repairs[1]			
Cover System Component	**Problem**	**Allowable Limits**	**Repair if Allowable Limits are Exceeded**
Cover System	Cover System Subsidence	ponding > 1" or gullying / erosion	▸ backfill with additional cover material (TP-1, silty sand with gravel) to achieve lines and grades of original final cover surface ▸ minimize any flow concentration locations (potential pooling or erosion areas)
		see Table 2	▸ remove Protection Layer and GCL in area of subsidence ▸ place light weight fill to achieve lines and grades of original subgrade ▸ replace / repair GCL ▸ replace Protection Layer
	Embankment Slope Instability	no signs of excessive embankment movement or surface cracks greater than 1"	▸ remove erosion protection ▸ reconstruct embankment with additional embankment material (TP-1, silty sand with gravel) to achieve lines and grades of original embank surface (or flatter) and minimize any flow concentration locations (potential pooling or erosion areas) ▸ add toe berm along base of slope in failure area ▸ replace erosion protection
	gully development on impoundment top	depth > 1"	backfill to original grade with similar material type (TP-1, silty sand with gravel)
	gully development at embankment crest or on outslope	depth > 2"	backfill to original grade with similar material type (D_{50} = 1" rock)
	gully development from normal flow channel in diversion channel parallel to and at toe of impoundment outslope	no gullying allowed	▸ replace/repair any disturbed erosion protection (either D_{50} = 1" or D_{50} = 3" rock) ▸ backfill gully to original grade with native materials ▸ grade normal flow channel within diversion channel away from impoundment embankment
	gully development in diversion channel at any other location in diversion channel	NA	no repair required
	seepage through embankment	no seepage allowed	▸ remove embankment material in seepage area ▸ repair GCL liner and/or tie-in with original impoundment liner ▸ replace embankment material ▸ replace erosion protection
Runoff Control System	excessive silt build up at fence lines in diversion channel	allowed if not effecting cover system	▸ clear silt, organics, debris ▸ modify diversion channel alignment and/or gradients

1 EPA 1988 - Guide to Technical Resources for the Design of Land Disposal Facilities

Table 1
Problem Identification, Allowable Limits, and Repairs[1]

Cover System Component	Problem	Allowable Limits	Repair if Allowable Limits are Exceeded
Cover System	Cover System Subsidence	ponding > 1" or gullying / erosion	▸ backfill with additional cover material (TP-1, silty sand with gravel) to achieve lines and grades of original final cover surface ▸ minimize any flow concentration locations (potential pooling or erosion areas)
		see Table 2	▸ remove Protection Layer and GCL in area of subsidence ▸ place light weight fill to achieve lines and grades of original subgrade ▸ replace / repair GCL ▸ replace Protection Layer
	Embankment Slope Instability	no signs of excessive embankment movement or surface cracks greater than 1"	▸ remove erosion protection ▸ reconstruct embankment with additional embankment material (TP-1, silty sand with gravel) to achieve lines and grades of original embank surface (or flatter) and minimize any flow concentration locations (potential pooling or erosion areas) ▸ add toe berm along base of slope in failure area ▸ replace erosion protection
	gully development on impoundment top	depth > 1"	backfill to original grade with similar material type (TP-1, silty sand with gravel)
	gully development at embankment crest or on outslope	depth > 2"	backfill to original grade with similar material type (D_{50} = 1" rock)
	gully development from normal flow channel in diversion channel [illegible]	no gullying allowed	▸ replace/repair any disturbed erosion protection (either D_{50} = 1" or D_{50} = 3" rock) ▸ backfill gully to original grade with native materials ▸ grade normal flow channel within diversion channel away from impoundment embankment
	[illegible]	NA	no repair required
	[illegible]	no seepage allowed	▸ remove embankment material in seepage area ▸ repair GCL liner and/or tie-in with original impoundment liner ▸ replace embankment material ▸ replace erosion protection
Runoff Control System	[illegible]	allowed if not effecting cover system	▸ clear silt, organics, debris ▸ modify diversion channel alignment and/or gradients

If seepage occurs through the liners, then a drain may need to be installed, to keep from occurring again. this accordingly

1 EPA 1988 - Guide to Technical [illegible] al Facilities

Cover System subsidence monitoring will be conducted by a visual inspection of the surface and a survey of the six installed settlement monuments. If the visual inspection, or settlement monument survey results, show that different areas of the cover are subsiding at substantially different rates (ponding greater than 1" and/or erosion and gullying), then a further and more detailed survey shall be conducted to delineate the area(s) of differential subsidence, and the amount(s) of maximum subsidence in each area. As noted in Table 1, there are separate repair methods for the two allowable subsidence limits listed. The first repair method is for "minor" differential subsidence, or that which will not potentially lower the permeability of the GCL. This method basically consists of adding Protection Layer material to achieve the original cover surface elevations and grades. The second repair method is for "significant" differential subsidence, or that which may lower the permeability of the GCL. If the calculated maximum differential settlement for a subsidence area is less than that shown in Table 2 below, then the first level of repair is adequate. If the calculated maximum differential settlement for a subsidence area is greater than that shown in Table 2, then the second level of repair will be required. Cumulative subsidence, and corresponding levels of repair, must be taken into account over time.

Table 2
Guidelines for Allowable Differential Settlement

Radius of subsidence area (ft)	Maximum Differential Settlement (in each subsidence area) (ft)
1	0.2
2	0.4
5	1.0
10	2.0
25	5.0

Guidelines for maximum subsidence that GCL can withstand without damage (i.e., any lowering increase in permeability. (Daniel 1995)

Preventative Maintenance Activities

Preventative maintenance may be required for two to three years after completion of cover construction. As listed in Table 2 on the following page, maintenance activities in specific areas may include, but are not limited to the following activities:

- **minor differential subsidence** - place additional Protection Layer material to minimize flow concentration locations
- **large / potentially damaging differential subsidence** - remove Protection Layer and GCL, place light weight fill to achieve lines and grades of original subgrade, replace / repair GCL, replace Protection Layer
- **excessive movement or failure of impoundment embankments** - remove erosion protection, reconstruct embankment with additional material to achieve lines and grades of original

embankment surface and minimize any flow concentration locations, add toe berm along base of slope, replace erosion protection

- **excessive surface erosion (gullying)** - place additional Protection Layer to achieve original lines and grades, place additional erosion protection or other materials as required
- **gullying at toe of the impoundment within the diversion channel** -backfill gully to original grade with native materials, replace/repair disturbed erosion protection, grade normal flow channel within diversion channel away from impoundment embankment toe
- **excessive siltation** - clean / clear soil, organics, or other deleterious materials from diversion channel or fences, modify diversion channel alignment and/or gradients
- **leachate migration** - remove embankment material in seepage area, repair GCL liner and/or tie-in with original impoundment liner, replace embankment material, replace erosion protection

Long-Term Maintenance and Monitoring Plan

Annual Site Inspection Form 1

2003 - Apex Site - Pond 2 Reclamation

Date:______________________________ Inspector:________________________________

Recent Weather:_____________________ Approximate Precipitation Amount:____________

Site Perimeter (site boundary / outlying areas up to 1/4 mile away)	
Observed Condition:	
Observed Damage:	

Site Perimeter (property fence / gate)	
Observed Condition:	
Observed Damage:	
Corrective Actions Required:	

Site Perimeter (all upgradient areas)	
Observed Condition:	
Observed Damage:	

Long-Term Maintenance and Monitoring Plan

Annual Site Inspection Form 2

2003 - Apex Site - Pond 2 Reclamation

Date:______________________	Inspector:______________________
Recent Weather:______________________	Approximate Precipitation Amount:______________
Impoundment (top and outslopes,)	
Observed Performance:	
Observed Damage:	
Corrective Actions Required:	
Impoundment (Protection Layer - top surface materials)	
Observed Performance:	
Amount and Location of Differential Subsidence:	
Observed Damage:	
Corrective Actions Required:	
Impoundment (Surface Layer - erosion protection)	
Observed Performance:	
Observed Damage:	
Corrective Actions Required:	

Long-Term Maintenance and Monitoring Plan

Annual Site Inspection Form 3

2003 - Apex Site - Pond 2 Reclamation

Date:______________________________	Inspector:______________________________
Recent Weather:____________________	Approximate Precipitation Amount:____________
Diversion Channel	
Observed Performance:	
Observed Damage:	
Corrective Actions Required:	

Long-Term Maintenance and Monitoring Plan

Annual Site Inspection Form 4

2003 - Apex Site - Pond 2 Reclamation

Settlement Monument Survey Results			
Settlement Monument	Settlement This Period (inches)	Total Settlement (inches)	Location Requires Fill Material (Y/N)

Other Settlement Location Survey Results			
Settlement Location	Settlement This Period (inches)	Total Settlement (inches)	Location Requires Fill Material (Y/N)

Long-Term Maintenance and Monitoring Plan - Annual Site Inspection Checklist 2003 - Apex Site - Pond 2 Reclamation			
Cover System Component	**Potential Problem**	**Allowable Limits**	**Limits Exceeded (Y/N)**
Cover System	Cover System Subsidence	Minor: ponding > 1" some gullying / erosion	
		Significant: see Table 2	
	Embankment Slope Instability	excessive embankment movement or surface cracks > than 1"	
	gully development on impoundment top	depth > 1"	
	gully development at embankment crest or on outslope	depth > 2"	
	gully development from normal flow channel in diversion channel parallel to and at toe of impoundment outslope	no gullying allowed	
	gully development in diversion channel at any other location in diversion channel	NA	NA
	seepage through embankment	no seepage allowed	
Runoff Control System	excessive silt build up at fence lines in diversion channel	allowed if not effecting cover system	

Guidelines for Allowable Differential Settlement	
Radius of subsidence area (ft)	**Maximum Differential Settlement (in each subsidence area) (ft)**
1	0.2
2	0.4
5	1.0
10	2.0
25	5.0

Guidelines for maximum subsidence that GCL can withstand without damage (i.e., any lowering increase in permeability. (Daniel 1995)

Appendix I

Construction Quality Control Plan

Appendix I - Construction Quality Control Plan

Summary

This Construction Quality Control Plan (CQCP) is for Hecla Mining Company's Pond 2 Final Closure Plan at the Apex Site near St. George, Utah. It presents how specific Construction Quality Control (CQC) activities will be applied during the project to ensure that construction meets the design intent. CQC activities will include direct monitoring, observation, testing, and control of the quality of final cover system construction at the site.

CQC refers to measures taken by the Contractor(s) / Installer(s) to determine compliance with the requirements for materials and workmanship as stated in the plans and specifications for the project. CQC will be performed by the General Contractor (GC), Earthwork Contractor (EC), and Geosynthetics Installation Contractor(s) (IC). Manufacturing Quality Control (MQC), which is direct monitoring and control during the manufacture of geosynthetic materials, will be performed by manufacturer(s). Each manufacturer's MQC data and information and CQC installation requirements will be provided by the IC's.

Responsibilities and Qualifications of Personnel

Responsibilities of key personnel will be identified prior to initiation of construction. Responsibilities of those personnel associated with the project are outlined in Table 1 at the end of this Appendix. Minimum recommended qualifications of each of the key personnel are listed in Table 2 at the end of this Appendix.

Background

The Apex Site is located approximately 15 miles northwest of St. George, Utah on land leased from the Shivwits Band of the Paiute Tribe. The Site can be accessed through the OMG facility on which it is located. The Site encompasses a total area of approximately 8 acres. Pond 2 (the impoundment) is a synthetically-lined waste containment facility which is roughly circular with an area of approximately 5 acres. The lining consists of a fabric-reinforced spray-on asphaltic membrane approximately one quarter (1/4) to one half (½) inch in thickness. Hecla removed and disposed a variety of on-site materials into Pond 2 including:

- gallium and germanium extraction process wastes (solutions and solids)
- cobalt-sulfate recovery process wastes
- ore stockpile materials
- old impoundment liner materials
- subsoils

Some of these materials were mixed with lime and limestone prior to disposal, while others were dredged and pumped into the impoundment as a slurry. During site cleanup work, the perimeter embankment was raised approximately five feet (5') to provide sufficient capacity for material disposal. The embankment raise was constructed utilizing on-site soils (clay to cobble sizes) over the centerline of the existing embankment. The raise was unlined and the crest is approximately ten feet (10') wide. The embankment ranges from three feet (3') to seven feet (7') above the existing ground surface with outslopes that range from approximately 2:1 (H:V) to 3:1. Currently the impoundment has a temporary rock and topsoil cover which is approximately two (2') to four and one-half (4½') feet thick.

Project Objective

The general objective of the project is to construct a three-layered final cover system on Pond 2 (the impoundment) which will provide hydraulic isolation for wastes in the impoundment, and which will perform effectively over the long-term. Specifically, the work required to complete this project consists of the following activities:

- management of storm water, sediment and dust
- drainage and consolidation of waste materials currently within the impoundment
- burial of minimal amounts of additional on-site wastes (primarily geosynthetic liners and associated salts)
- removal of a portion of the existing impoundment embankment
- regrading the existing temporary cover and embankment materials after placement on the top surface
- rebuilding the impoundment embankment
- constructing the final cover system
- excavating a diversion channel around the reclaimed impoundment
- placing erosion protection

Construction Quality Control (CQC) Requirements

CQC verification activities (observations, inspections, and testing) are associated with both the earthen and geosynthetic materials to be installed and constructed. During construction each earthen and geosynthetic material component must be inspected to ensure that it has not been damaged during its installation or during construction of another component. Any damage that does occur must be repaired, and these corrective measures must be documented. Earthen materials CQC verification activities will include:

- screening incoming materials
- observing and testing constructed fills
- observing construction procedures
- measuring final cover layer thickness
- surveying final grades

CQC observations, inspections, and testing frequencies for the earthen materials are presented in Table 3 at the end of this Appendix.

Earthworks Specifications

Specifications for earthen materials used in each portion of the project are summarized in Table 4 at the end of this Appendix.

Geosynthetic CQC

Specific CQC activities associated with GCL construction and Wick Drain installation will be based on manufacturer's CQC manuals and installation requirements, and the project Specifications. These activities will include, but will not be limited to, measurement and observation of:

- manufactured thickness, width, and length
- protective covering
- marking and identification
- loading, shipment, and unloading
- site storage
- subgrade preparation
- deployment - manufacturer to provide site-specific panel layout plan
- low ground pressure deployment equipment
- verification of no damage to GCL that has been dragged during deployment
- protection from potential wind damage

Field Inspection Forms

Example CQC inspection and reporting forms which may be used during construction are attached. These forms allow for documentation of observations of typical construction activities including.

- Sediment Control Inspection
- Daily Work and Equipment Approval
- Daily Construction Activity / Inspection Report
- Daily Work Summary
- Daily Construction Summary Report
- Surveyor's Daily Time Log
- Erosion Protection Sieve Analysis
- Progress Review and Coordination Meeting (includes problem identification and corrective action)
- Drawings of Record (to be provided by CQC Surveyor)

The following CQC Inspection and Reporting forms will be provided by CQA Engineer and Installation Contractors, and approved by Owner's Representative prior to construction.

- Materials Test Reports (earthen materials)
- Geosynthetic (wick drain and GLC)

Table 1
Organization / Personnel Responsibilities

Organization/ Personnel	Responsibilities
USEPA	▸ permitting agency ▸ reviews permit application / final cover system plan ▸ reviews all CQA documentation during and after construction to confirm CQA plan was followed and that cover system was constructed as specified
Owner	▸ owns project ▸ designs, constructions, and maintains cover system ▸ complies with EPA requirements ▸ submits CQA documentation assuring EPA that cover system was constructed as specified
Owner's Representative	▸ official representative of Owner ▸ coordinates schedules, meetings, and field activities ▸ communicates to Owner, EPA, material suppliers, GC, IC, EC and CQA Engineer
Design Engineer	▸ designs cover system that fulfills operational requirements of Owner ▸ complies with accepted design practices that meet or exceed minimum requirements of EPA ▸ involved in CQA process
Manufacturers	▸ manufactures geosynthetic clay liner (GCL) and Wick Drains
General Contractor (GC)	▸ constructs overall cover system ▸ provides for CQC during construction ▸ purchases materials that meet specifications ▸ contracts with manufacturers of GCL and wick drains to supply material ▸ contracts with IC's ▸ controls overall construction operations, including scheduling and CQC ▸ primarily ensures that cover system is constructed according to specifications ▸ communicates with Owner and CQA Engineer regarding scheduling and occurrence of all construction activities
Installation Contractor (IC)	▸ handles, stores, places, and installs GCL ▸ has CQC plan which details proper manner of handling, storage, placement, and installation of GCL and wick drains ▸ communicates with Owner and CQA Engineer regarding scheduling and occurrence of all GCL construction activities
Earthwork Contractor (EC)	▸ grades site to elevations and grades shown on the plans and specifications ▸ constructs earthen components of cover system ▸ obtains suitable earthen materials ▸ transports, stores, pre-processes (if necessary), places, and compacts materials ▸ protects materials during and after placement ▸ carries out earthwork functions according to plans and specifications ▸ has CQC plan (or agree to one written by others) ▸ conducts CQC operations aimed at controlling materials and their placement so that they conform to the specifications ▸ communicates with Owner and CQA Engineer regarding scheduling and occurrence of all earthwork activities
CQC personnel	▸ works for GC, IC and/or EC ▸ is thoroughly familiar with the specifications to ensure that materials and installation procedures conform to the contract standards ▸ makes construction crews aware of the relative "fragile" nature of the cover system components.

Table 1

Organization / Personnel Responsibilities

CQA Engineer	▸ oversees overall CQA inspections ▸ reviews CQA plan, general plans, and specifications so that CQA can be implemented with no contradictions or unresolved discrepancies ▸ educates CQA inspection personnel on CQA requirements and procedures, and special steps that are needed on the cover system project ▸ schedules and coordinates CQA inspection activities ▸ ensures that proper procedures are followed ▸ ensures that testing laboratories conform to CQA requirements and procedures ▸ confirms that test data are accurately reported and that test data are maintained for later reporting ▸ prepares periodic reports ▸ confirms that overall cover system was constructed in accordance with plans and specifications ▸ notifies Owner of non-conformances ▸ recommends work stoppages and possible remedial actions.
CQA personnel	▸ makes observations and performs field tests to ensure that cover system is constructed in accordance with plans and specifications ▸ reports to CQA Engineer

Table 2
Recommended Personnel Qualifications

Individual	Minimum Recommended Qualifications
Design Engineer	Registered Professional Engineer
Owner's Representative	Specific individual designated by Owner with knowledge of the project, its plans, specifications, and CQC/CQA documents.
GCL Manufacturer	Experience in manufacturing at least 10,000,000 square feet of similar materials.
Wick Drain Manufacturer	Experience in manufacturing at least 10,000,000 linear feet of similar materials.
MQC Personnel	Manufacturer or trained personnel in charge of MQC of the GCL / wick drains to be used in the project.
MQC Officer(s)	Individuals specifically designated by the manufacturer(s) in charge of GCL / Wick Drain material MQC.
GCL / Wick Drain Installer's Representatives	Experience installing at least 10,000,000 square feet / 1,000,000 linear feet of similar GCL / Wick Drains, respectively.
CQC Personnel	▸ employed by GC, IC, or EC ▸ qualified / certified in particular area of work being tested / observed
CQA Personnel	▸ employed by an organization that operates separately from the GC and Owner ▸ qualified / certified in particular area of work being tested /observed
CQA Engineer	▸ registered Professional Engineer employed by an organization that operates separately from the GC and Owner ▸ competent and experienced in similar projects ▸ hired by Owner ▸ functions separately from Contractors and Owner

Table 3
CQC Observations, Inspections, and Testing Frequencies

Material	Observation/ Inspection	Test	Minimum Test Frequency[2]	
			Suggested Time Interval	cy/test
Borrow[1]				
General Fill Materials: Temporary Cover Materials, Existing Embankment Materials, General Earth Fill	Daily[3]	Grain Size / Sieve Analysis (ASTM D422)	1 per day	4,000
		Standard Proctor (ASTM D698)	1 per day	4,000
Protection Layer Materials	Daily	Grain Size / Sieve Analysis (ASTM D422)	2 per day	2,000
		Standard Proctor (ASTM D698)	1 per day	4,000
		Atterberg Limits (ASTM D4318)	1 per day	4,000
		Moisture Content (ASTM D2216)	2 per day	2,000
Erosion Protection	Daily[4]	Gradation (ASTM C136) Sieve Analysis (ASTM D422)	NA	100
Constructed Facility				
Vertical Wick Drains	Continuous	Observation[5]	NA	NA
Regraded Temporary Cover (subgrade): Temporary Cover Materials, Existing Embankment Materials, General Earth Fill	Daily[6]	In-place moisture / density (ASTM D1556)	2 per day	2,000
Embankment (General Earth Fill)	Daily	In-place moisture / density (ASTM D1556)	2 per day	1,000
Barrier Layer (GCL)	Continuous	Observation[5]	NA	NA
Protection Layer (General Earth Fill)	Daily[3]	In-place moisture / density (ASTM D1556)	2 per day	2,000
Surface Layer (Erosion Protection)	Continuous	Observation and Thickness	4 per day	50

Notes for Table 3 (following page):

1. Perform all tests when borrow material characteristics change, or 1 per day, whichever is greater.
2. Presented as a guide to CQC personnel. Testing frequency may be higher due to material availability. Similarly, the testing frequency of the index tests, i.e., Atterberg, Grain Size, and Gradation, may be decreased should material uniformity support a lower testing frequency. Specified time interval testing frequencies are for continuous construction activities, and should be modified accordingly for those tasks where construction is intermittent. The testing frequency of tests per cubic yard shall govern frequency.
3. Embankment excavation to be monitored continuously during excavation activities.
4. Erosion protection production facility to be observed once daily during production of rock.
5. Verification of material per Manufacturer's manufacturing quality control (MQC) plan for materials shipped to site, and verification of installation per Manufacturer's CQC requirements.
6. Final subgrade surface shall meet all requirements of GCL CQC plan.

Table 4
Earthworks Specifications Summary

Constructed Feature	Fill Type	Gradation		Maximum Loose Lifts	Moisture Content	Compaction
		Sieve Size	% Passing (by wt.)			
Temporary Cover	Temporary Cover	NA	NA	1 foot	NA	90% ASTM D698 or minimum 4 passes w/ smooth-drum, vibratory compactor ≥10 tons
	Existing Embankment	NA	NA	1 foot	NA	90% ASTM D698 or minimum 4 passes w/ smooth-drum, vibratory compactor ≥10 tons
	General Earth	4 inch	100	1 foot	NA	90% ASTM D698
Embankment	General Earth	4 inch	100	1 foot	NA	90% ASTM D698
Barrier Layer	GCL	NA	NA	NA	NA	NA
Protection Layer	General Earth	2 inch	100	1 foot[1]	NA	Use LGP[2] Equipment 85% ASTM D698[3]
Surface Layer	Rock	D_{50} = 1"	NA	2"[4]	NA	NA
Diversion Channel	Rock	D_{50} = 3"	NA	6"[4]	NA	NA

Notes:
1. 1 foot loose lift minimum thickness to protect GCL (Barrier Layer).
2. LGP = Low Ground Pressure
3. Maximum compaction of 85% ASTM D698 - no heavy equipment on Protection Layer until final grading being conducted
4. Required layer thickness

Example CQC Inspection and Reporting Forms

Sediment Control Inspection Form

2003 - Apex Site - Pond 2 Reclamation

Date:________________________ Inspector:________________________

Prec. Type & Amount:________________________ Rainfall Duration:________________________

AREA:________________________	
Observed Performance:	
Observed Damage:	
Corrective Actions (if any):	
AREA:________________________	
Observed Performance:	
Observed Damage:	
Corrective Actions (if any):	
AREA:________________________	
Observed Performance:	
Observed Damage:	
Corrective Actions (if any):	
AREA:________________________	
Observed Performance:	
Observed Damage:	
Corrective Actions (if any):	
AREA:________________________	
Observed Performance:	
Observed Damage:	
Corrective Actions (if any):	
AREA:________________________	
Observed Performance:	
Observed Damage:	
Corrective Actions (if any):	

Contractor's Supervisor: ________________________ Construction Manager: ________________________

Daily Work and Equipment Approval

2003 - Apex Site - Pond 2 Reclamation

Report Number: ____________________ Date: ____________________

Project: ____________________ Day: ____________________

Work Project	Work to Be Addressed/ Equipment to Be Used Today
Surface Water Runoff Dust Control	
Settlement Monuments	
Vertical Wick Drains	
Temporary Containment Berms	
Evaporated Salts Collection Ditch Evaporation Ponds	
GCL	
Protection Layer	
Erosion Protection	
Miscellaneous Other	

Contractor's Supervisor: ____________________ Construction Manager: ____________________

Daily Construction Activity / Inspection Report

2003 - Apex Site - Pond 2 Reclamation

Client: ____________________	**Date:** ____________________
Location: ____________________	**Daily Report Number:** ________ **Sheet:** ________ **of:** ______

To: ____

Weather: ____

On-Site Contractor and Equipment: ____

Construction Activities: ____

Verbal Communication with Contractor, Engineer, Designer, Owner: ____________________

______________________________ Construction Manager

______________________________ Approved by

Daily Work Summary

2003 - Apex Site - Pond 2 Reclamation

Report Number: ____________ Date: ____________

Project: ____________ Day: ____________

Equipment		Description / Operator	Hours Worked Today	Working Area
Dozers				
Scraper				
Loaders				
Excavator				
Grader				
Compactor				
Backhoe				
Truck				
Pickup				
Other				
Labor		**Name**	**Hours**	**Working Area**
Supervisor				
Grade Str.				

Material / Equipment	Hours Today	Hours Previous	Hours Total	Volume Today	Volume Previous	Volume Total

Contractor's Supervisor: ____________ Construction Manager: ____________

Daily Construction Summary Report Day - , , 2003

Weather AM/PM

Contractor Work

-
  -
  -
  -
-
  -
  -
  -

Other Activities

Communications/Meetings:

-
  -
  -
  -
-
  -
  -
-
  -
  -
  -

Materials Testing:

Additional Issues

On-site Equipment:

Visitors:

Construction Manager ____________________________

Surveyor's Daily Time Log

2003 - Apex Site - Pond 2 Reclamation

Date: ______________ Day: ______________ Per Diem (man days): ______________

Time On-Site: ______________ Time Off-Site: ______________ Daily Travel Time (total): ______________

Work Area	Preconstruction Survey	Time (hrs)	Topographic Work	Time (hrs)	Verification Survey	Time (hrs)	Construction Staking	Time (hrs)	Other	Time (hrs)

Contractor's Supervisor: ______________ Construction Manager: ______________

Erosion Protection Sieve Analysis

2003 - Apex Site - Pond 2 Reclamation

Project: ______________________ Date: ______________________

Tested By: ______________________ Sample ID: ______________________

Sieve Size (inches)	Weight Retained (lbs)	Percent Retained (%)	Percent Passing (%)
Total Weight (lbs) =			**= Total % Retained**

Measured D_{100} (inches)	
Sample Median Diameter (D_{50}) (inches)	

$\frac{2.5 - D_{50}}{2.5 - 2.0} = \frac{\_\_\_\_ - \_\_\_\_}{\_\_\_\_ - \_\_\_\_}$
D_{50} = ______
D_{25} = ______
D_{15} = ______

Progress Review and Coordination Meeting

2003 - Apex Site - Pond 2 Reclamation

Meeting Date: ______________________ Location: ______________________

Attendees: ______________________ ______________________

______________________ ______________________

______________________ ______________________

Work Schedule (see attached sheet)/quantities/status vs schedule)

Planned Work (equipment/manpower changes/potential conflicts or problems)

Specific Problems (lump sum work/hourly work/change order status)

Contract Items (work/bid clarifications/progress payments)

Safety

Contractor's Supervisor

Construction Manager